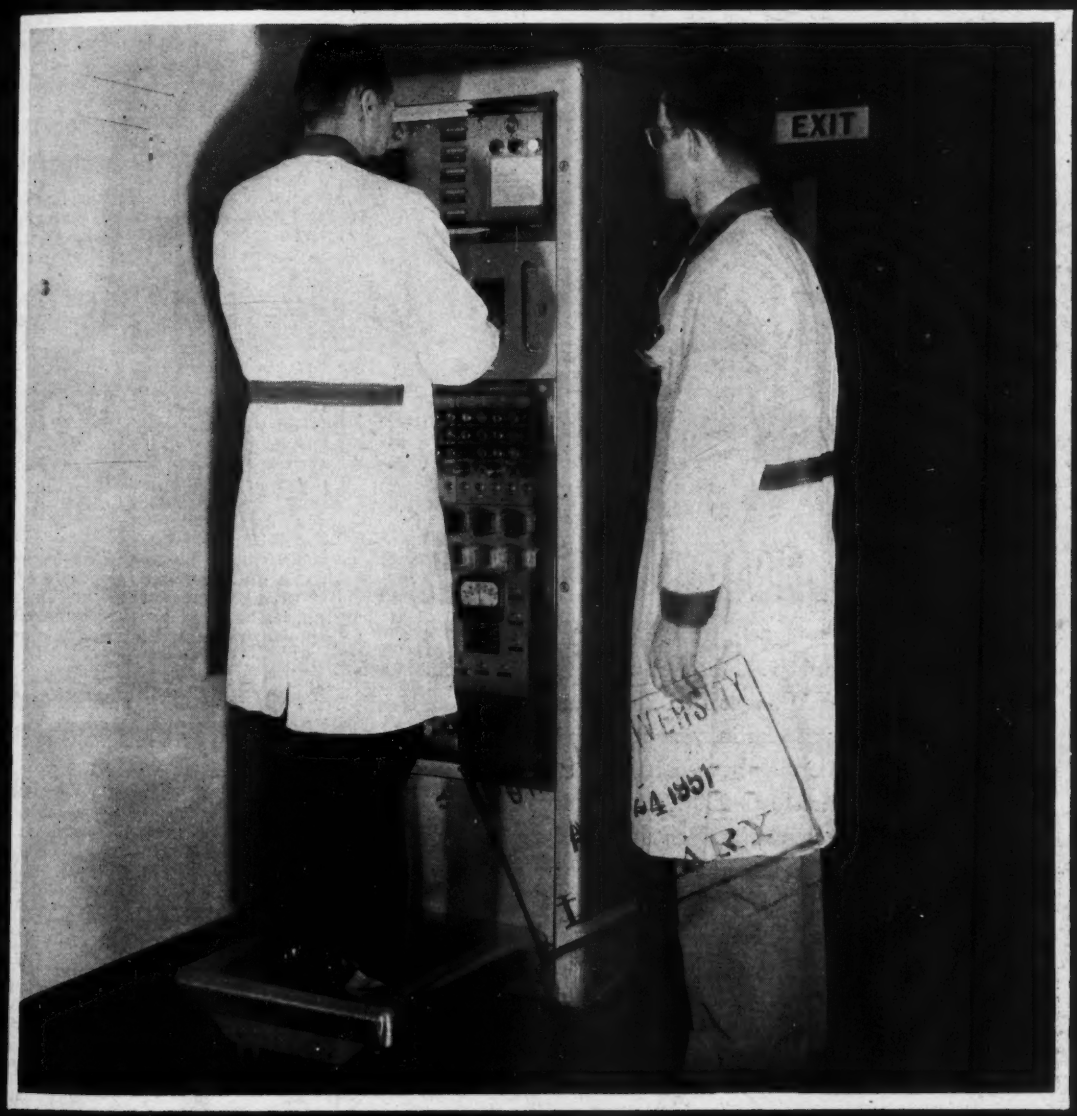
Instruments

THE MAGAZINE of MEASUREMENT and CONTROL

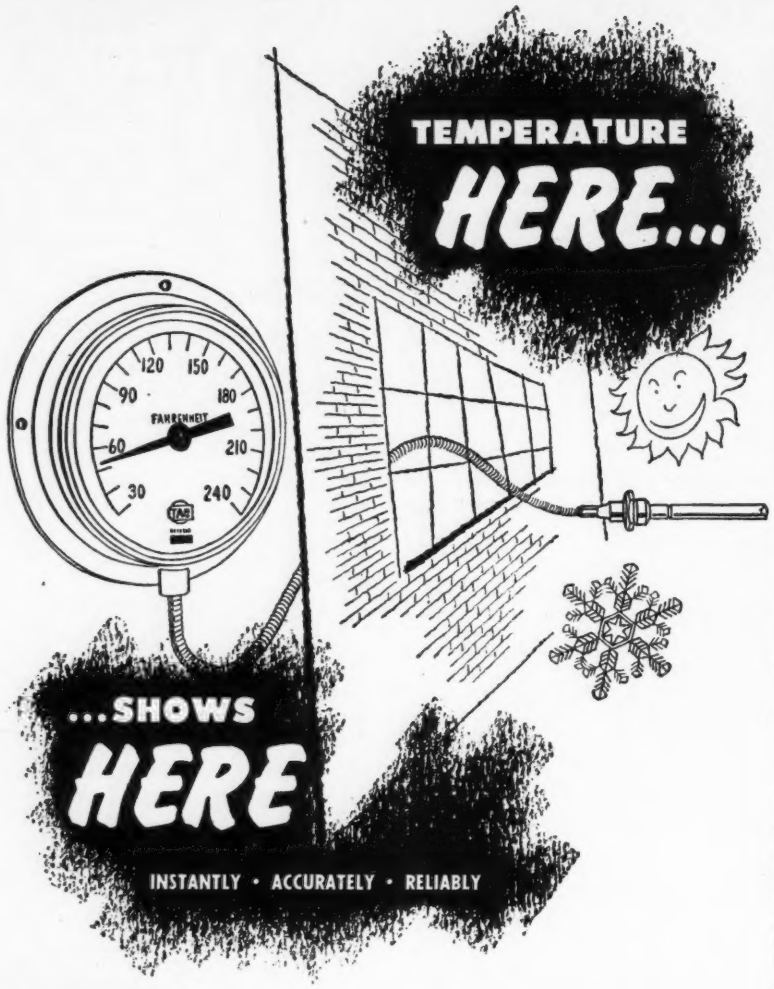
Vol. 24 APRIL 1951 No. 4

INCLUDING THE *Journal of the Instrument Society of America*

AND THE *Journal of the Southern California Meter Association*



AEC personnel working with radioactive materials at the Brookhaven National Laboratory use the "Beta-Gamma Hand and Foot Checker" to determine contamination. *(Photo courtesy The Austin Company).*



•TAG DIAL-INDICATING THERMOMETERS

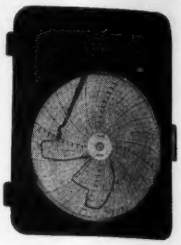
Around corners . . . through walls . . . from one floor to another—TAGliabue Dial Thermometers indicate true temperatures year in, year out. Needing no connection to any power supply, these sturdy instruments give readings as remote as 250 feet through temperature-compensated capillaries. Ranges extend from −300°F. to +1000°F. Accuracy is unaffected by vibration or severe shock.

Use these versatile TAG Thermometers for marine, power plant, refrigeration system or heating equipment applications—in fact, *wherever* you need to know temperatures immediately, accurately, dependably. Be sure you have full information on file.

TAGLIABUE INSTRUMENTS DIVISION
Weston Electrical Instrument Corporation
614 Frelinghuysen Avenue, Newark 5, New Jersey

"TAG" Temperature Recorders Chart from −300° to +1000°F.

Accurate written records of varying temperatures are charted by the Temperature Recorders produced by TAGliabue Instruments Div., Dept. 67, Weston Electrical Instrument Corp., Newark 5, N. J. Temperatures as low as −300°F. or as high as +1000°F. can be recorded with these versatile instruments.



Various types of actuations in TAG Temperature Recorders achieve scale expansion for utmost precision over the working ranges. Interchangeable tube systems are laboratory calibrated at the factory. A safety link provides over-range protection. Details are given in Catalog 1210.

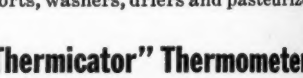
Self-Operating Controllers Hold Precise Temperatures

Temperatures between the limits of 20 and 300°F. are accurately maintained by the line of Self-Operating Controllers manufactured by TAGliabue Instruments Div., Dept. 67, Weston Electrical Instrument Corp., Newark 5, N. J. These controllers are entirely self-contained, requiring no connection to any air or electrical power supply.

Available in styles for use on steam, hot water or refrigerant lines, TAG Self-Operating Controllers continuously adjust the supply of heating or cooling medium to maintain constant temperature despite changing thermal conditions. Typical applications include water heaters, tanks, retorts, washers, driers and pasteurizers.

"Thermicator" Thermometer Used With or Without Case

Convenience is outstanding in the new "Thermicator" pocket-type thermometer introduced by TAGliabue Instruments Div., Dept. 67, Weston Electrical Instrument Corp., Newark 5, N. J. This simplified instrument can be used as either an armored or a plain thermometer.



The "Thermicator" consists of an etched-stem glass thermometer and its non-corroding protective case. Slimmer than most fountain pens, it is secured in any depth pocket by an adjustable clip. There is no cap to unscrew; the thermometer is held in the case by spring pressure and is whisked free or replaced in a single motion.

The "Thermicator" is 6" long, ⅜" in diameter, and is graduated in 2° divisions. Ranges are —30 to +120°F. (spirit-filled) and 0 to +220°F. (mercury-filled). Entire bore is visible.

Eliminate Incidental FM from A-M Measurements

on HF and VHF Equipment

Carrier Range . . . 5 to 220 Mc

Modulation Frequency . . . 20 to 15,000 Cycles

The G-R Type 1023-A Amplitude Modulator is designed to produce an a-m signal, with no significant FM, from standard-signal generators.

It is particularly useful for checking the performance of such apparatus as voice ground-to-air communication equipment; air navigation Omnirange and ILS; telemetering and remote control equipment using AM.

It provides a means of adding AM, without incidental FM, to F-M signal generators, so that simultaneous measurements of a-m rejection and f-m response can be made on equipment used in such services as FM, TV, telemetering and remote control.

It also makes an unmodulated test oscillator into a modulated signal source, free from FM.

With most A-M signal generators incidental FM may be as high as 20 kc at 50 Mc and 80 to 100% modulation. Use of the Type 1023-A Amplitude Modulator will result in an improvement of as much as 1000 to 1.

One of its features is a second range of 10.1 to 11.3 Mc. At 10.7 (the RMA standard F-M receiver intermediate frequency) this range provides a gain of 10 with a band-width to the half-points of ±0.6 Mc, gain and modulation percentage being substantially independent of input voltage at levels up to 0.1 volt. Output voltages up to 3 volts can be obtained without serious increase in envelope distortion, with some change in gain.

Modulation up to 80% is provided, either internal at power-line frequency or external from 20 to15,000 cycles. Envelope distortion is less than 5% at 80% modulation. From 1 microvolt to 1.5 volts gain and modulation percentage are practically independent of r-f input voltage.

Type 1023-A Modulation Monitor . . . $250

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VOLTMETERS • FREQUENCY STANDARDS
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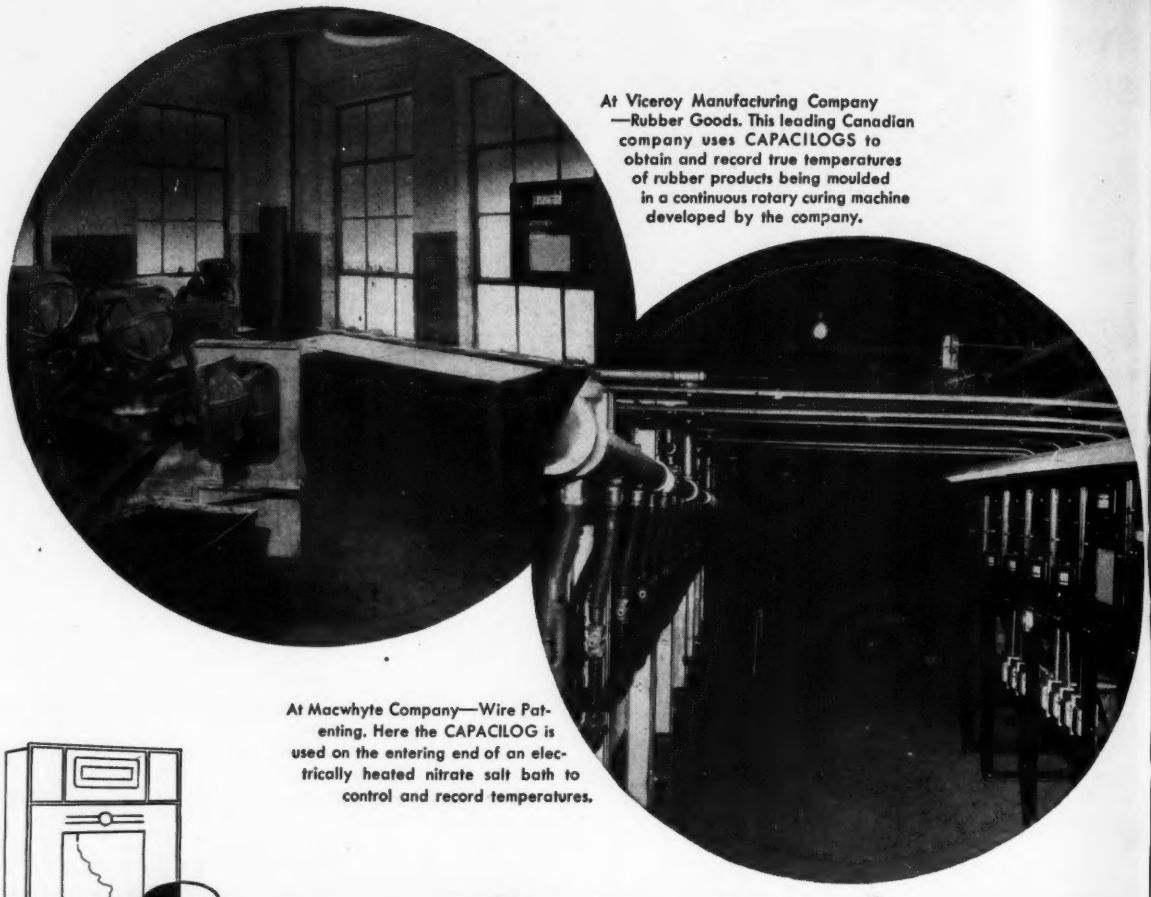


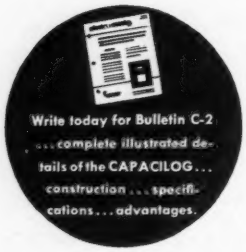
At Viceroy Manufacturing Company —Rubber Goods. This leading Canadian company uses CAPACILOGS to obtain and record true temperatures of rubber products being moulded in a continuous rotary curing machine developed by the company.

At Macwhyte Company—Wire Patenting. Here the CAPACILOG is used on the entering end of an electrically heated nitrate salt bath to control and record temperatures.

instrumentality in action...for accuracy

Accurate to a point which exceeds the need in normal process applications throughout industry—that's the Capacilog—another example of Wheelco Instrumentality in action. It's a direct reading, deflection type strip chart recorder which gives you measurement, indication, and control with a permanent record of temperature, speed, static strain loads, AC-DC voltage, amperage and other electrically measurable factors.

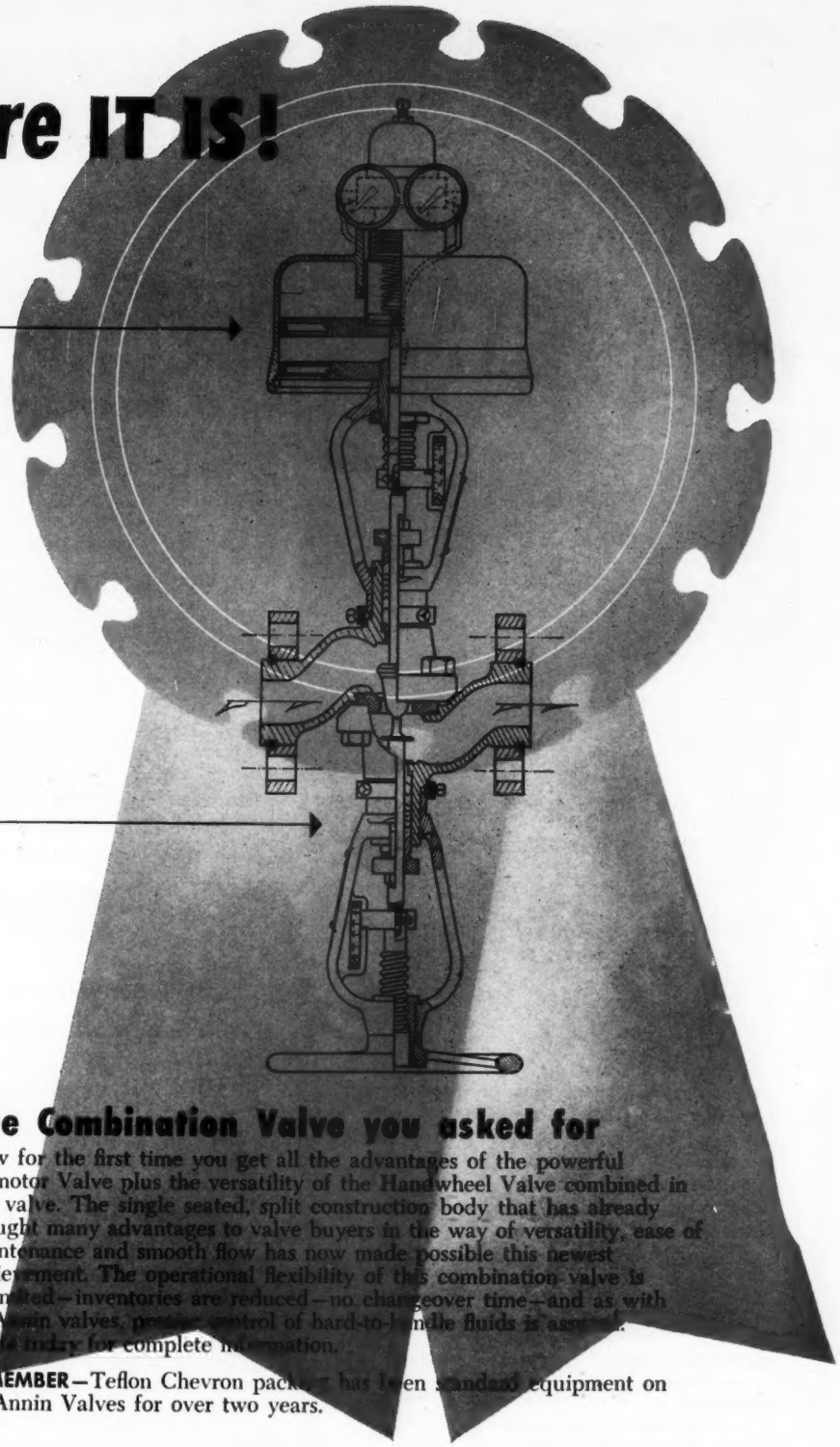
Economy—uninterrupted service and accuracy are the leading reasons why more and more manufacturers are specifying the Wheelco Capacilog for more profitable use of process equipment.



Wheelco Instruments Company, 833 West Harrison Street, Chicago 7, Illinois

wheelco *electronic controls*

Here IT IS!



AUTOMATIC

DOMOTOR—For Automatic Control—Sealed piston in dome, actuated by internally controlled differential pressures, insures powerful stable valve action. Built-in null type positioner unit. Light weight, economical and flexible with proven dependability.

MANUAL

HANDWHEEL—For Manual Control—Perfect for those start-up periods or for operation during instrument repair. Provides positive manual control when desired or may be used as an adjustable limit stop. Incorporates advantages of continually connected control valve without the usual mechanical complications.

The Combination Valve you asked for

Now for the first time you get all the advantages of the powerful Domotor Valve plus the versatility of the Handwheel Valve combined in one valve. The single seated, split construction body that has already brought many advantages to valve buyers in the way of versatility, ease of maintenance and smooth flow has now made possible this newest achievement. The operational flexibility of this combination valve is unlimited—inventories are reduced—no changeover time—and as with all Annin valves, precise control of hard-to-handle fluids is assured. Write today for complete information.

REMEMBER—Teflon Chevron packing has been standard equipment on all Annin Valves for over two years.

ANNIN CONTROL VALVES

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3500 Union Pacific Avenue, Los Angeles 23, California

-from design
to installation
of instruments

FALSTROM

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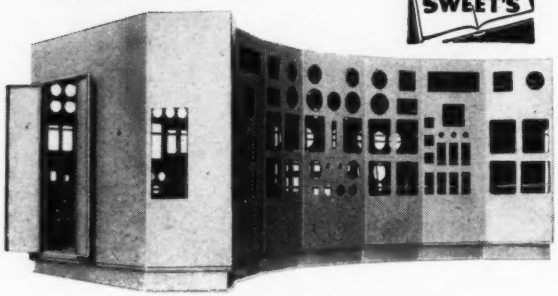

Walk-in Cubicle with front and rear control board (lighting canopy not shown in picture).

-service on control panels is complete!

Now you can look to Falstrom for complete service on panelboards, switchboards, cubicles, instrument panels, entire control centers and switchgear housings. Falstrom does considerably more than design and produce functional and distinctive, finished housings. The new Falstrom service includes piping, procurement and installation of instruments and other accessories as specified. All work performed at Falstrom is done by engineers and skilled technicians completely familiar with each phase of the installation. Check on this Falstrom service, now. Use the handy coupon below for details.

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☐ COMPLETE CONTROL CENTERS
☐ PIPING AND INSTRUMENT INSTALLATION

Instruments
THE MAGAZINE *of*
MEASUREMENT
and CONTROL

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LEWIS PORTABLE PYROMETER POTENTIOMETERS

FOR MEASURING TEMPERATURES ELECTRICALLY

- IN MOVING VEHICLES
- IN AIRCRAFT
- IN THE LABORATORY

ACCURATE, DIRECT-READING, EASILY-OPERATED INSTRUMENTS, WITH ELECTRICAL COLD-JUNCTION COMPENSATION.

These potentiometers have been used for years by the leading motor car and aircraft manufacturers for proving-ground and flight-test work as well as in the laboratory.

- Three models from which to choose the instrument for your application.
  Model 13PO2, with single temperature scale.
  Model 14PO (illustrated) with high and low temperature scales.
  Model 78PO with one temperature and one millivolt scale or two temperature scales, for different thermocouple materials.
- Housed in a sturdy hardwood case, approximately 11⅜" long, 10" wide and 7⅞" high. Weight approximately 17 lbs., shipping weight 20 lbs.
- For dependable temperature instrumentation, use these potentiometers with LEWIS leads, selector switches and thermocouples.

THE LEWIS ENGINEERING CO.

NAUGATUCK, CONNECTICUT

Manufacturers of Complete Temperature Measuring Systems for Aircraft

meet the newest member of the *FarriSeal* family

BalanSeal*

IT SAVED $75,000 IN PIPING WITH A $5,000 VALVE INVESTMENT**

Pioneered by Farris Engineering Corp., embodying advanced engineering technics, *and absolutely unique*—although it is now being imitated—the patented BalanSeal is ideally suited for use wherever a collecting system is required for a series of safety-relief valves. It permits a higher downstream pressure—and consequently, smaller piping. Yes! The cost of a BalanSeal valve installation is a mere fraction of the savings effected in down-stream piping. (**In one case, a cost reduction of $75,000 resulted from a $5,000 investment in BalanSeal Valves.)

In BalanSeal, the sole force opposing the opening of the valve is the spring. Downstream back pressure, static or surge, cannot act on the disc and has absolutely no effect on the relieving point.

BalanSeal is the ultimate in safety-relief valve design and construction. The bellows, which also distinguishes the FarriSeal design, is so proportioned as to eliminate any unbalanced forces on the valve disc—which is perfectly balanced on its seat at the set pressure. Like all other FarriSeal Valves, perfect protection is provided for guide, stem and spring by completely isolating these parts from the lading fluid.

Get the facts on the revolutionary BalanSeal Safety Relief Valve. Find out how you can cut installation costs to the bone, step up operating profits. Write for Bulletin No. 52B—it will pay off in ASSURED safety and installation economy.

*Patented and Patents Pending

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FARRIS ENGINEERING CORP.

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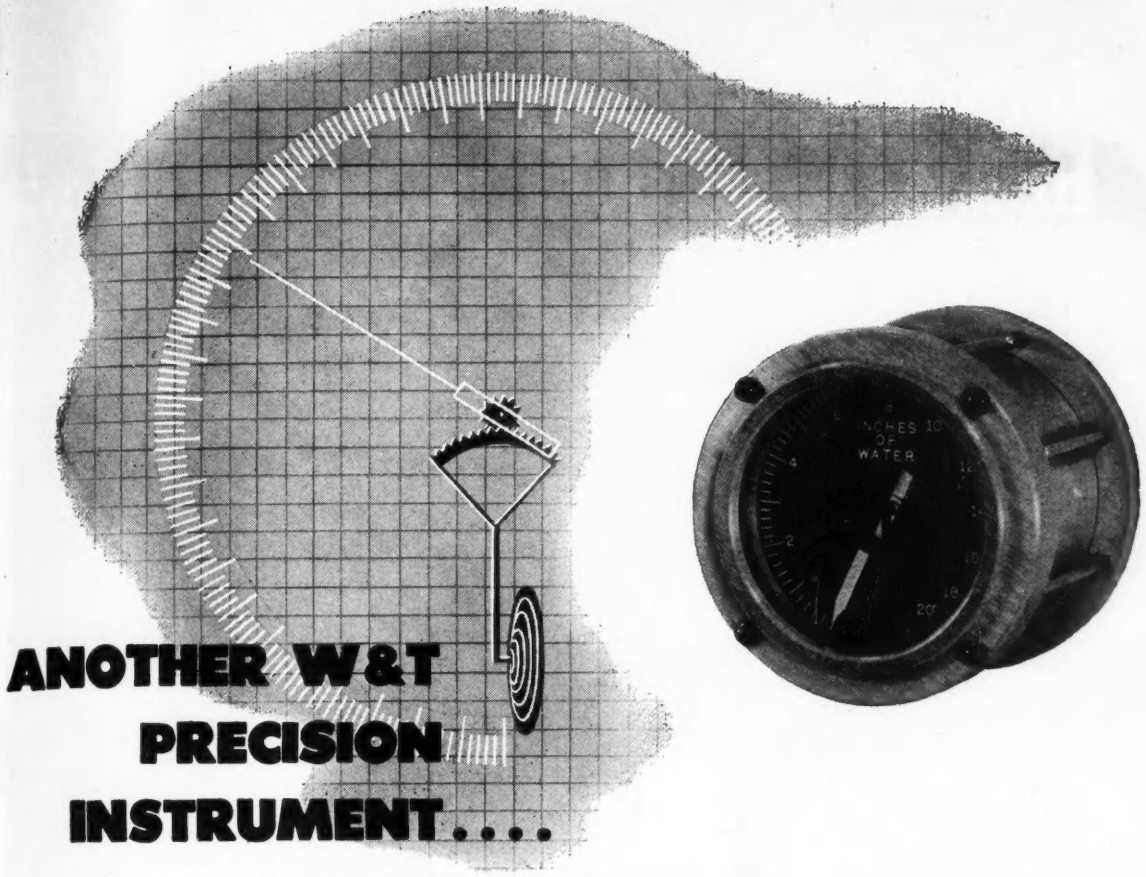

ANOTHER W&T PRECISION INSTRUMENT....

The W & T Precision Low Pressure Gauge

The W&T Precision Low Pressure Gauge has proved to be the answer to the problem of measuring low pressure accurately by successful use in such fields as aircraft flight testing, automotive research work, and engine and ventilation studies. Built with custom care from its beryllium copper capsule to its individually calibrated dial, the W&T Low Pressure Gauge is a precision instrument of the highest grade.

Here are some of its outstanding features:

Sensitive to 1 part in 500

Available in ranges from 0-10" of water to 0-400" of water

Measures differential pressure

Unaffected by gravity or acceleration

Equipped with expanded scale if desired

Write now and tell us your low pressure measuring requirements. We'll be glad to help — no obligation, of course.

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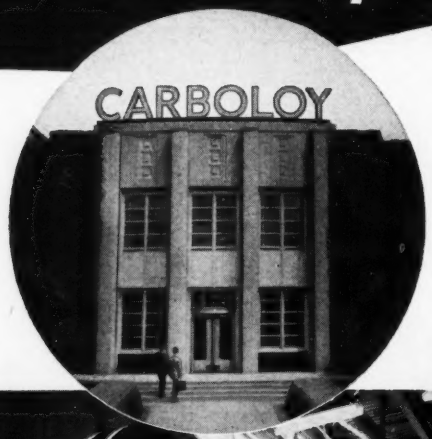
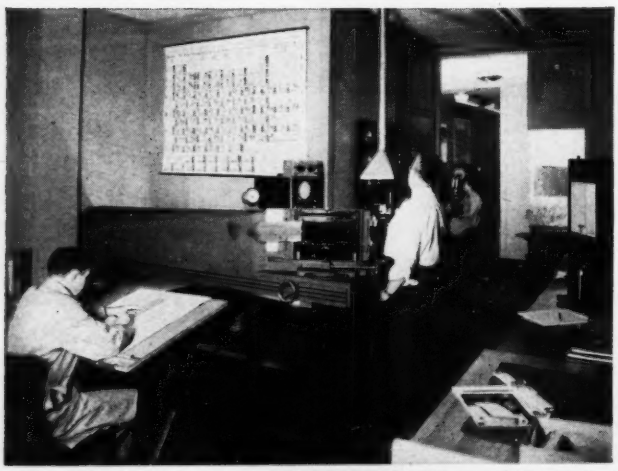
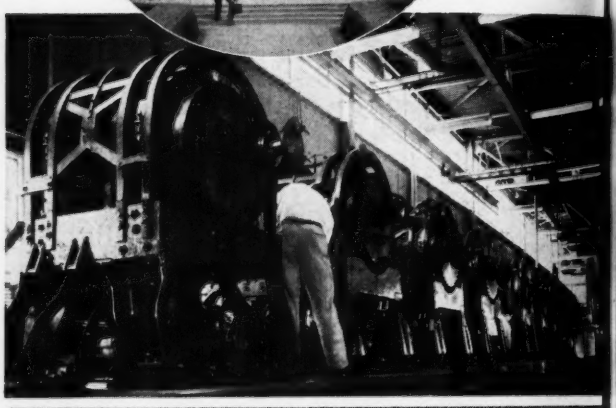
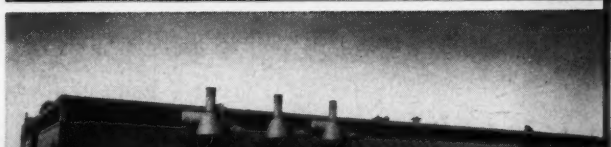
Typical views of our Detroit facilities for the manufacture of cemented carbides.









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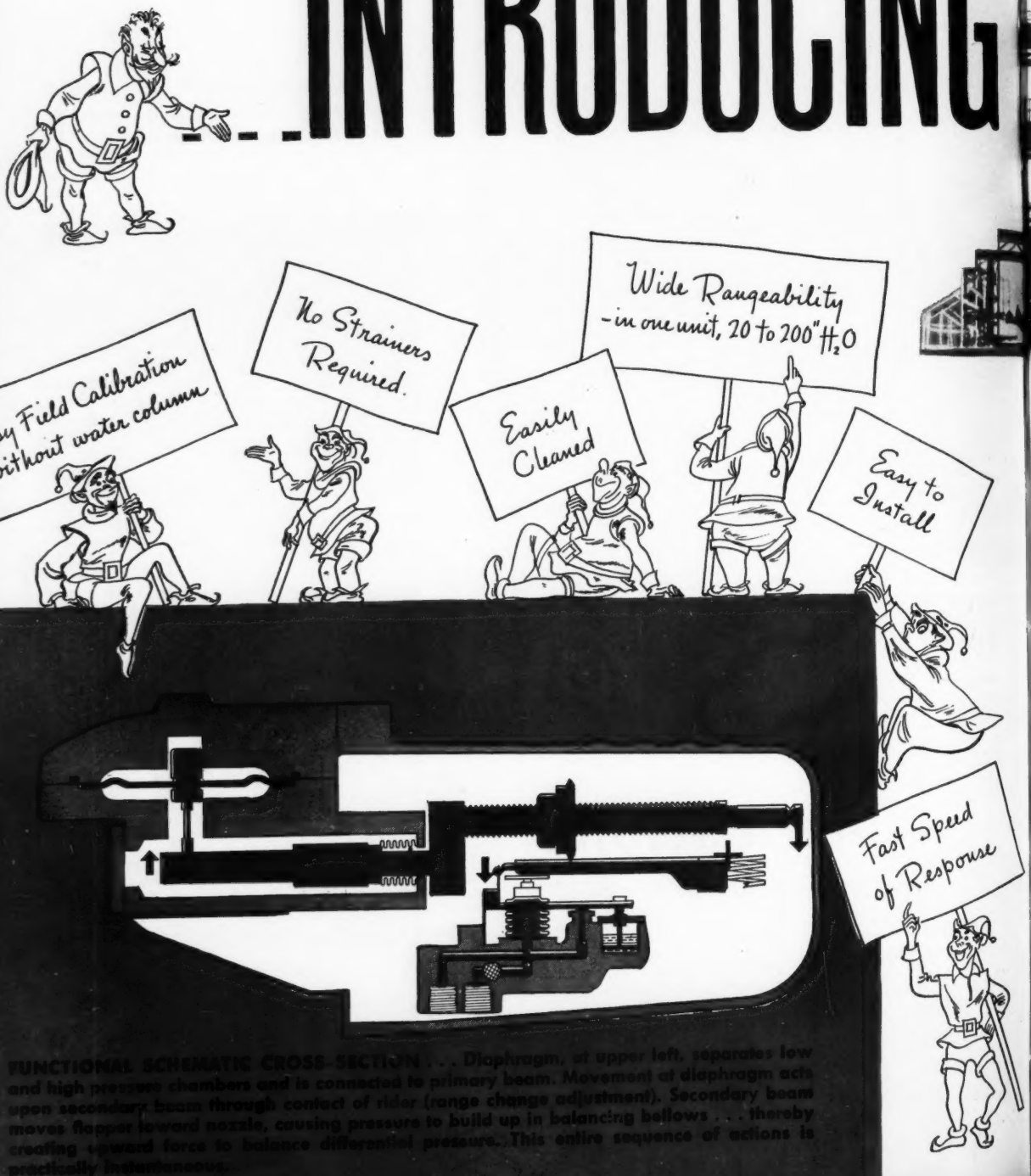
INTRODUCING

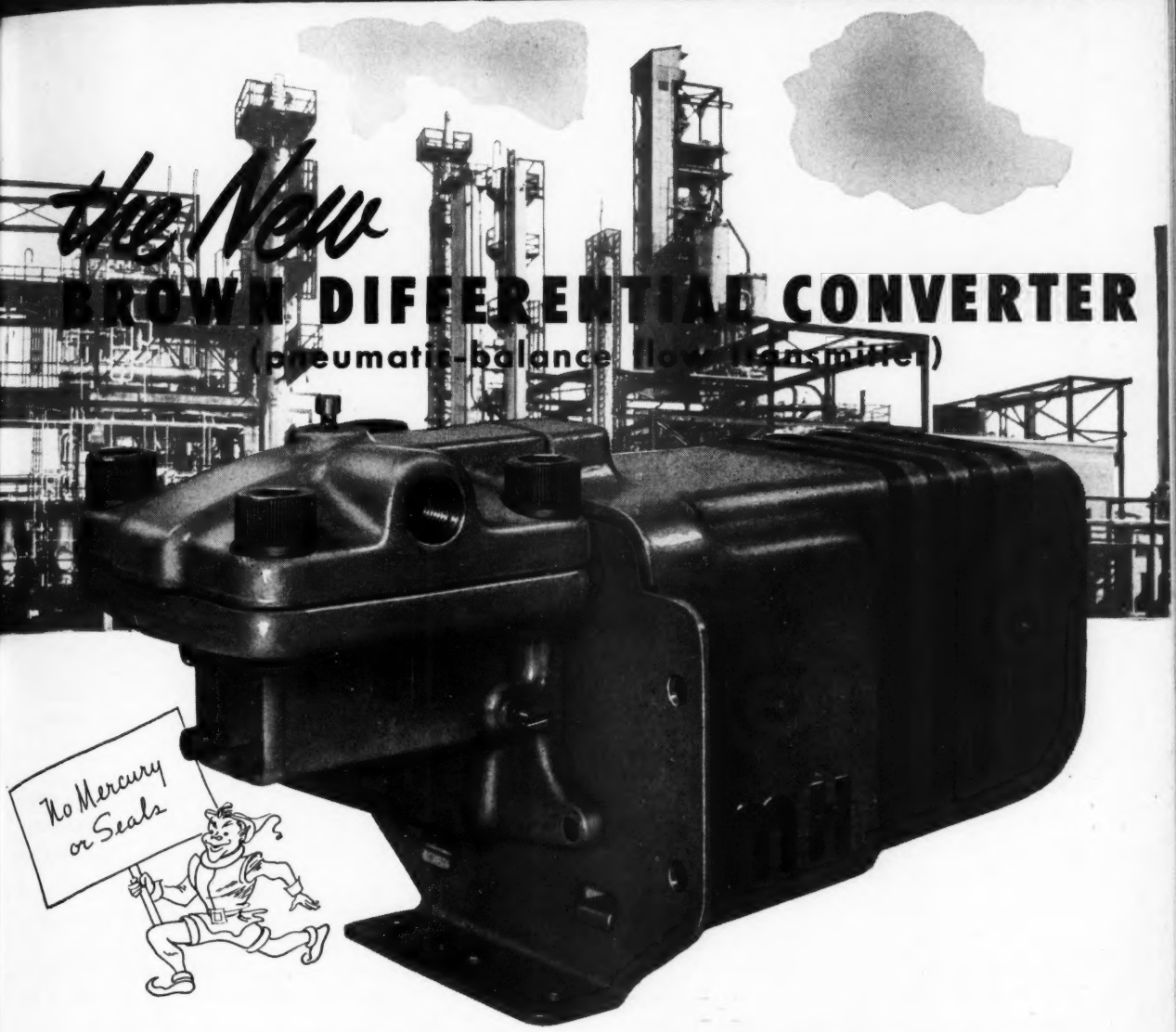


FUNCTIONAL SCHEMATIC CROSS-SECTION . . . Diaphragm, at upper left, separates low and high pressure chambers and is connected to primary beam. Movement of diaphragm acts upon secondary beam through contact of rider (range change adjustment). Secondary beam moves flapper toward nozzle, causing pressure to build up in balancing bellows . . . thereby creating upward force to balance differential pressure. This entire sequence of actions is practically instantaneous.

Measurement and Transmission of Flow

the New BROWN DIFFERENTIAL CONVERTER

(pneumatic-balance flow transmitter)



AFTER long and rigorous testing in the field, the Brown Differential Converter is ready to set new high standards of simplicity and precision in the measurement and transmission of flow.

Operating on the pneumatic-balance principle, this compact and light-weight unit converts differential pressure at the orifice into a proportionate output air pressure which is a measure of flow. All adjustments . . . such as the range change which is continuous from 0-20 inches of water up to 0-200 inches of water . . . are easily and simply made, without special tools or extra parts.

Applicable to a wide range of continuous processes, the Brown Differential Converter is the fore-runner of an entirely new series of pace-setting developments made possible through Brown *Creative Instrumentation*. For detailed information write for a copy of new Catalog No. 2281 . . . and call in our local engineering representative for a discussion of your process needs. Offices in more than 80 principal cities of the United States, Canada and throughout the world.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, 4482 Wayne Avenue, Philadelphia 44, Pa.

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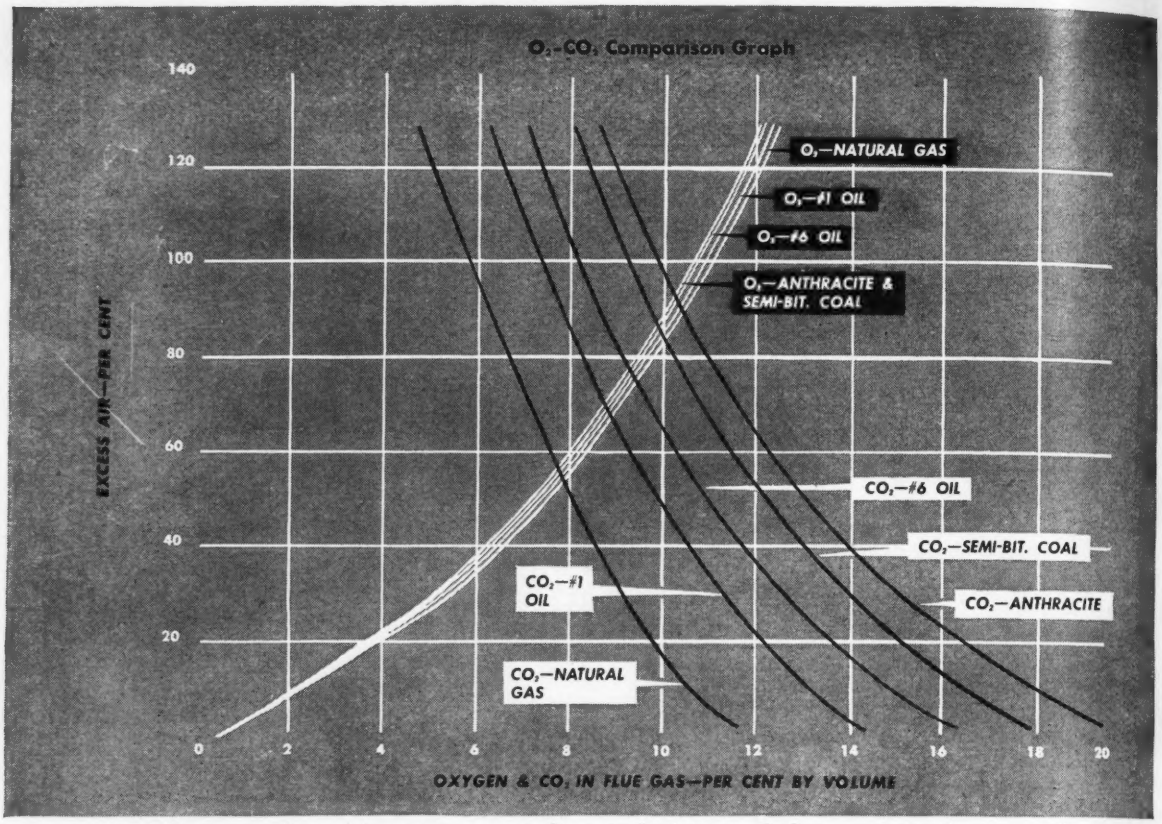
BROWN INSTRUMENTS

How to burn Multiple Fuels efficiently



Oxygen and Oxygen alone gives you an undistorted picture of the amount of excess air present.

When switching from one fuel to another or burning more than one fuel at the same time, you can realize large savings with a continuous indication of Oxygen content in your flue gas—because Oxygen and Oxygen alone gives you an undistorted picture of the amount of excess air present.

This fact is borne out by the graph showing the relationship of excess air to CO_2 and O_2 in the flue gas of five common fuels. While the O_2 curves nearly coincide (especially in the important 30% excess air range) the CO_2 curves diverge widely.

Large Savings Possible

This deviation was costing a medium sized refinery in Michigan $35-40 per day in boiler room fuel costs. Burning a combination of oil and gas they found that a combustion control system to handle their multiple fuel firing conditions would cost more than their small boilers.

They purchased a Hays Magno-Therm Oxygen Recorder, and immediately found that their boiler operation was so inefficient that the pen would not stay on the 0-10% chart. However, by operating with reference to the O_2 recorder they were able to reduce fuel costs enough *to pay for the instrument in 40 days.*

With the Hays Magno-Therm Oxygen Recorder you get:

Continuous, highly accurate indication and recording.
Complete compensation for temperature and pressure effects.
Freedom from chemicals or hazardous fuel burning in the analyzing process.
Swift, sure electronic operation.

If you are facing the problem of multiple fuel combustion, you will want a detailed copy of this O_2-CO_2 Comparison Graph as well as Hays Bulletin 50-829—describing the Magno-Therm Oxygen Recorder. Write for this free information.

THE HAYS CORPORATION
MICHIGAN CITY 8, INDIANA

Automatic Combustion Control • Boiler Panels • Hays-Penn Flowmeters
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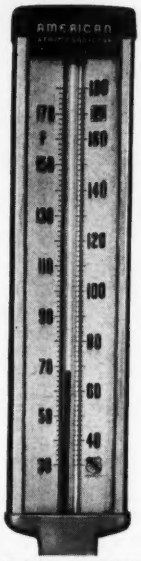
Temperature Indicating Or Recording Problem?

AMERICAN CAN SOLVE IT!



AMERICAN INDUSTRIAL GLASS THERMOMETERS

Full scale openings of 7", 9", or 12" with easy-to-read red mercury tubing. Straight and angle forms.

Tough or easy! Special or standard! If it's an application for a temperature indicator or recorder, there's an American Thermometer to fit the job.

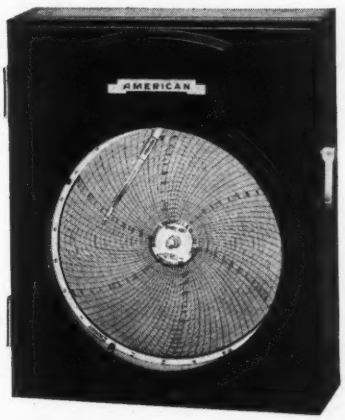
American Thermometers are available in industrial glass, dial and recording designs. They offer the widest selection in types of actuation and ranges. Beyond this, they provide the user with the highest standards of accuracy as well as readability.

Select from mercury, vapor pressure, gas, bi-metal, or thermocouple actuation; ranges from minus 320° F. to 3000° F. And famous "Magic Pulse" capillary tubing allows you to indicate or record temperatures up to 250 feet away from the temperature source.

Yes, American Thermometers are "typically American" . . . truly the finest you can use.

AMERICAN DIAL THERMOMETERS

Highly accurate with clear, bold figures on exactly graduated dials and with a pointer of contrasting color. Several types of cases for stem, wall, or flush mounting.



AMERICAN RECORDING THERMOMETERS

With single, double, or triple pens in round or rectangular cases. 10 inch chart with effective scale width of 3⅝ inches—ample for easy and accurate reading.

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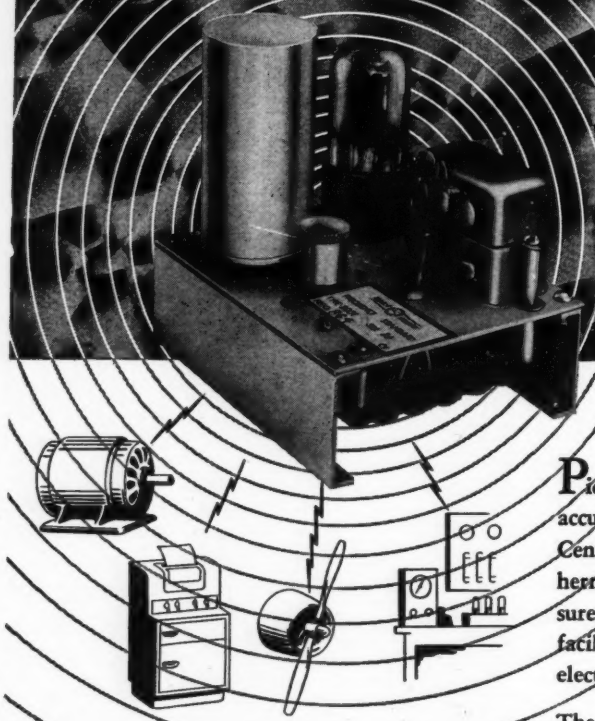
ANY FREQUENCY FROM 40 TO 1,000



Pictured here is a tuning-fork frequency standard with accuracy guaranteed to one part per million per degree Centigrade. The fork is temperature-compensated and hermetically sealed against variations of barometric pressure. This standard, when combined with basic equipment, facilitates accurate speed and time control by mechanical, electrical, acoustical or optical means.

The unit is available separately or in conjunction with complete timing instruments. Our engineers are ready to cooperate on any problem.

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American Time Products, Inc.

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A DIVISION OF WESTERN ELECTRIC COMPANY

• Internal
• Top Flange Mounted
Liquid Level Controller !

The new BS&B "Climax" Type 887 top flange mounted Liquid Level Control is the ideal, economical installation where a corrosive medium precludes the use of external piping. The type 887 is exactly the same as the amazing new 888 without lower cage housing. A hanger is provided to position the displacement element at the required level.

New Cone Point Pivot is practically friction-free. Torque tube and housing is *removable and reversible* without dismantling controller housing. You can employ *two* torque tube housings for two pilots and/or mercury switches!

Standard unit may be used for interface level control between two non-miscible liquids. Special floats available for specific gravity indication or control.

Available in three- and four-inch ASA flange sizes in iron, steel or special alloys. Larger size steel or special alloy flanges available for special applications. Write for new, fully illustrated catalog today!

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BS&B

"Climax" Type 887

INTERNAL TOP FLANGE MOUNTED LIQUID LEVEL CONTROLLER

here's a simple device to locate almost any kind of leak

NEW DPi LEAK DETECTOR MODEL LD-01

All you do is seal the sensitive element into the system being tested and bring the interior a little below atmospheric pressure. Then you direct a small jet of harmless Freon Gas at suspected spots and watch the meter. It's as simple as that, and sensitivity is high enough even where one-millionth of atmospheric pressure is to be maintained.

It works like this: The sensitive element contains a heated platinum anode and a cold cathode with relatively low voltage between them. The tendency of hot platinum to emit positive ions is enormously stimulated by infinitesimal traces of halogens or their compounds. The circuit to accomplish all this uses only three standard radio tubes and operates from your 115-v a-c lighting circuit.

For full information write ***Distillation Products Industries,*** Vacuum Equipment Department, 765 Ridge Road West, Rochester 3, N. Y. (Division of Eastman Kodak Company).

DPi

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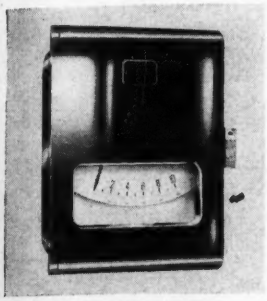
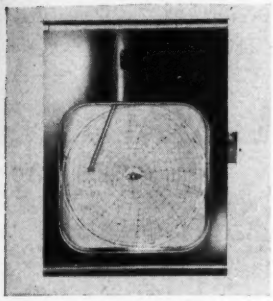
Also . . . high vacuum equipment . . . distilled monoglycerides . . . more than 3400 Eastman Organic Chemicals for science and industry

HOW TO SIMPLIFY PROBLEMS OF REMOTE MEASUREMENT AND CONTROL



THE TRANSMITTER



THE RECEIVER

Bristol Metameter* Telemetering Instruments Help Step Up Production... Save Time and Money... by Remote Measurement and Control of Pressure, Water Level, Flow, Temperature, Motion, Voltage, Current, Power and Totalized Load.

The Bristol Metameter Telemeter consists of three unit parts: Transmitter, Receiver, and interconnecting line which provides the electrical circuit between the two instruments.

The Transmitter is located close to the point of measurement. Its function is to transmit the readings to the receiver which can be any distance from a few feet to many miles away.

Readings can be transmitted over any two-wire circuit or its equivalent. Private wires, telephone circuits, radio (including microwave), or carrier current channels can be used.

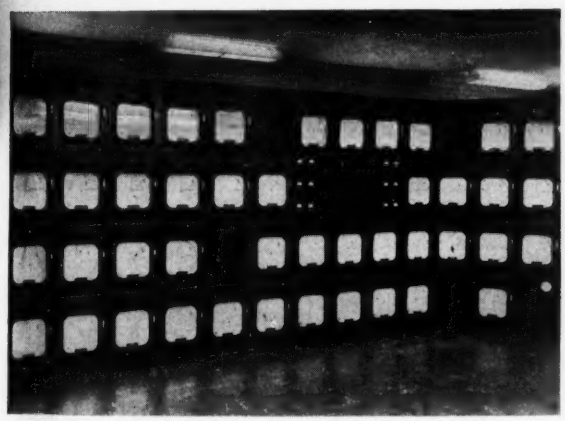
THE TRIED AND PROVED TELEMETERING SYSTEM. Bristol Metameter Telemeter is the product of 37 years of pioneering research and development work. Bristol's continuous program of engineering research and development keeps the Metameter abreast of modern requirements, making it the most reliable and widely used instrument in the field of telemetering.

A few of the thousands of Bristol Metameter Telemeter users:

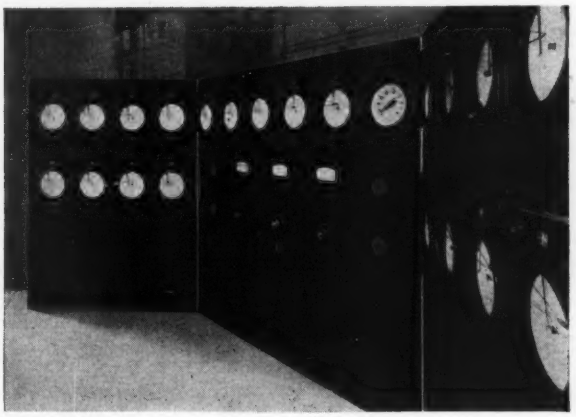
Standard Oil (Indiana), Flintkote, Jones & Laughlin Steel, Bethlehem Steel, Corn Products Refining Company, Champion Paper & Fibre, Mathieson Chemical, New York Central System, McCarthy Chemical, Weirton Steel, Eastman Kodak, United Piece Dye Works, Freeport Sulphur, U. S. Weather Bureau, Bonneville Power Administration, Woodward Iron, Celanese Corporation, Anaconda Copper.

**Reg. U.S. Pat. Off.*

WRITE US FOR BULLETIN M1700. THE BRISTOL COMPANY, 113 BRISTOL ROAD, WATERBURY 20, CONN.



UNITED STATES STEEL CORPORATION These Recording Metameter Receivers provide fuel dispatcher with information concerning gas fuel supply and demand throughout plant at Gary, Ind., help maintain highest production of steel with lowest fuel cost.



AT THE FORD PLANT Metameter Receivers used by the Ford Motor Company in dispatching gas throughout its Dearborn plant, bring readings of pressure and flow to central point for use of dispatchers. This installation has been in operation since 1936.

THE DEPENDABLE GUIDEPOST OF INDUSTRY

BRISTOL

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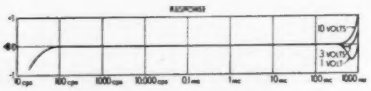
Complete Coverage! 2 to 700,000,000 cps

precision voltmeters for every ac voltage measuring need!

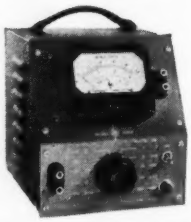
INSTRUMENT	PRIMARY USES	FREQUENCY RANGE	VOLTAGE RANGE	INPUT IMPEDANCE	PRICE
-hp- 400A	General purpose ac measurement	10 cps to 1 mc	.005 to 300v 9 ranges	1 megohm 24 μμfd shunt	$185.00
-hp- 400B	Low frequency ac measurements	2 cps to 100 kc	.005 to 300v 9 ranges	10 megohms 24 μμfd shunt	$195.00
-hp- 400C	Wide range ac measurements High sensitivity	20 cps to 2 mc	.0001 to 300v 12 ranges	10 megohms 15 μμfd shunt	$200.00
-hp- 404A	Portable, battery operated	2 cps to 50 kc	.0005 to 300v 11 ranges	10 megohms 20 μμfd shunt	$185.00
-hp- 410B	Audio, rf, VHF measurements; dc voltages; resistances	20 cps to 700 mc	0.1 to 300v 7 ranges	10 megohms 1.3 μμfd shunt	$245.00

New -hp- 410B Vacuum Tube Voltmeter

Gives same wide range and flat response performance as -hp- 410A voltmeter, but sets new standard of mechanical convenience, ease of operation, minimum bench space. Readily detachable probe leads fit in handy compartment in new, compact, streamlined case. Special diode probe design places capacity of approximately 1.3 μμfd across circuits under test. Shunt impedance is extremely high—10 megohms at low frequencies—thus circuits under test are not disturbed and true voltage readings are assured. New -hp- 410B provides 1 db accuracy from 20 cps to 700 mc; and may be used as a voltage indicator up to 3,000 mc. Also serves as audio or dc voltmeter or ohmmeter.



Response, -hp- 410B Voltmeter



-hp- 400C Vacuum Tube Voltmeter

General purpose precision voltmeter offering wide range, high sensitivity, high stability. Quick-reading linear meter scale shows RMS volts or dbm direct from −72 dbm to +52 dbm. Broad usefulness includes direct noise or hum measurements, transmitter and receiver voltages, audio, carrier or supersonic voltages, or power gain. Also may be used as 54 db amplifier to increase signal level to oscilloscopes, recorders, power amplifiers, etc.

-hp- 404A Battery-Operated Voltmeter

Precision vacuum tube instrument for general voltage measurement where ac power is not available. Compact, portable, splash-proof—ruggedly constructed for field operations. Wide voltage range permits all types of measurements including remote broadcast line and carrier checks, strain gauge system tests, telemetering and geophysical circuit measurements, etc. In the laboratory, offers completely hum-free measurements of very low noise level.

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HEAT APPARATUS • HEAT TRANSFER EQUIPMENT • STEAM JETS • CONDENSERS • CONDENSATE AND VACUUM PUMPS • GAS BOOSTING EQUIPMENT

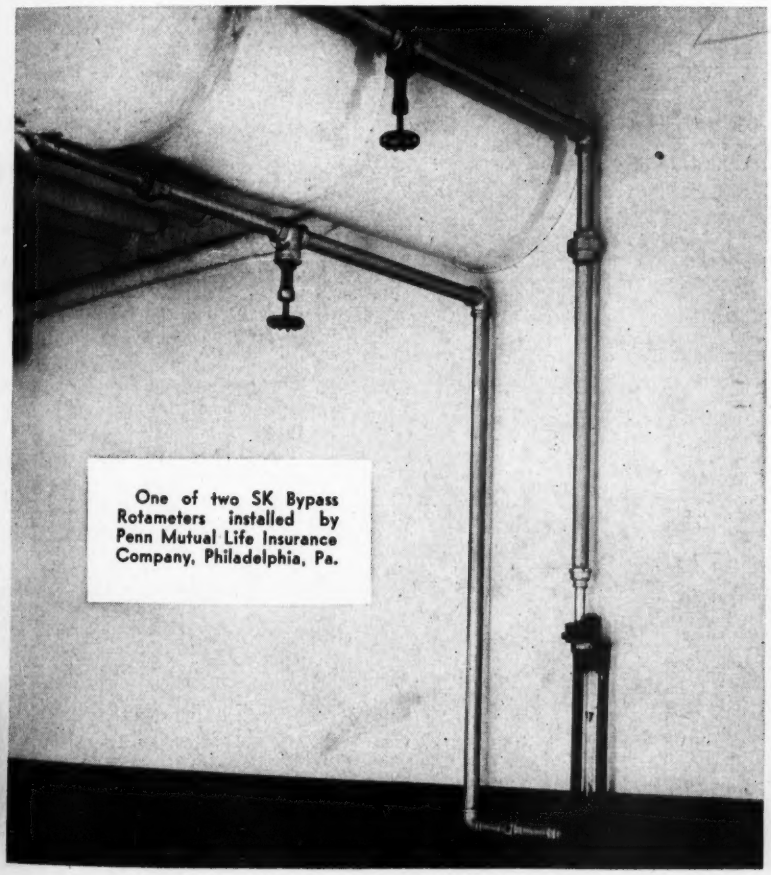
METERING FLOW IN LARGE PIPE LINES NO PROBLEM AT PENN MUTUAL

A typical application of an SK Bypass Rotameter is shown in the illustration below. Designed for measuring flow rate in pipes larger than 3", this type Rotameter can be arranged for horizontal flow, vertical flow up or vertical flow down.

The particular Rotameter shown in the photo is one of two such instruments which are installed in the air conditioning machinery room of the Penn Mutual Life Insurance Company, Philadelphia, Pa. Here, they measure water flow rate to the condensers and chillers of the air conditioning refrigerating machinery.

Prior to the installation of the Bypass Rotameters, there was no way of determining the quantity of chilled and condenser waters available to the equipment. The instruments were installed to supply this data.

For a condensed bulletin on all types of SK Rotameters, request Bulletin 18-*RA.*

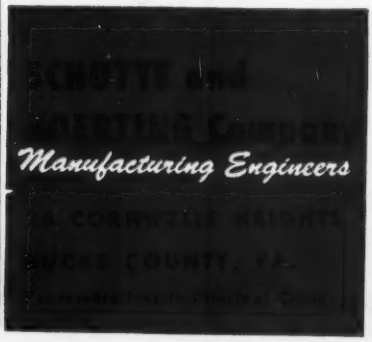


One of two SK Bypass Rotameters installed by Penn Mutual Life Insurance Company, Philadelphia, Pa.

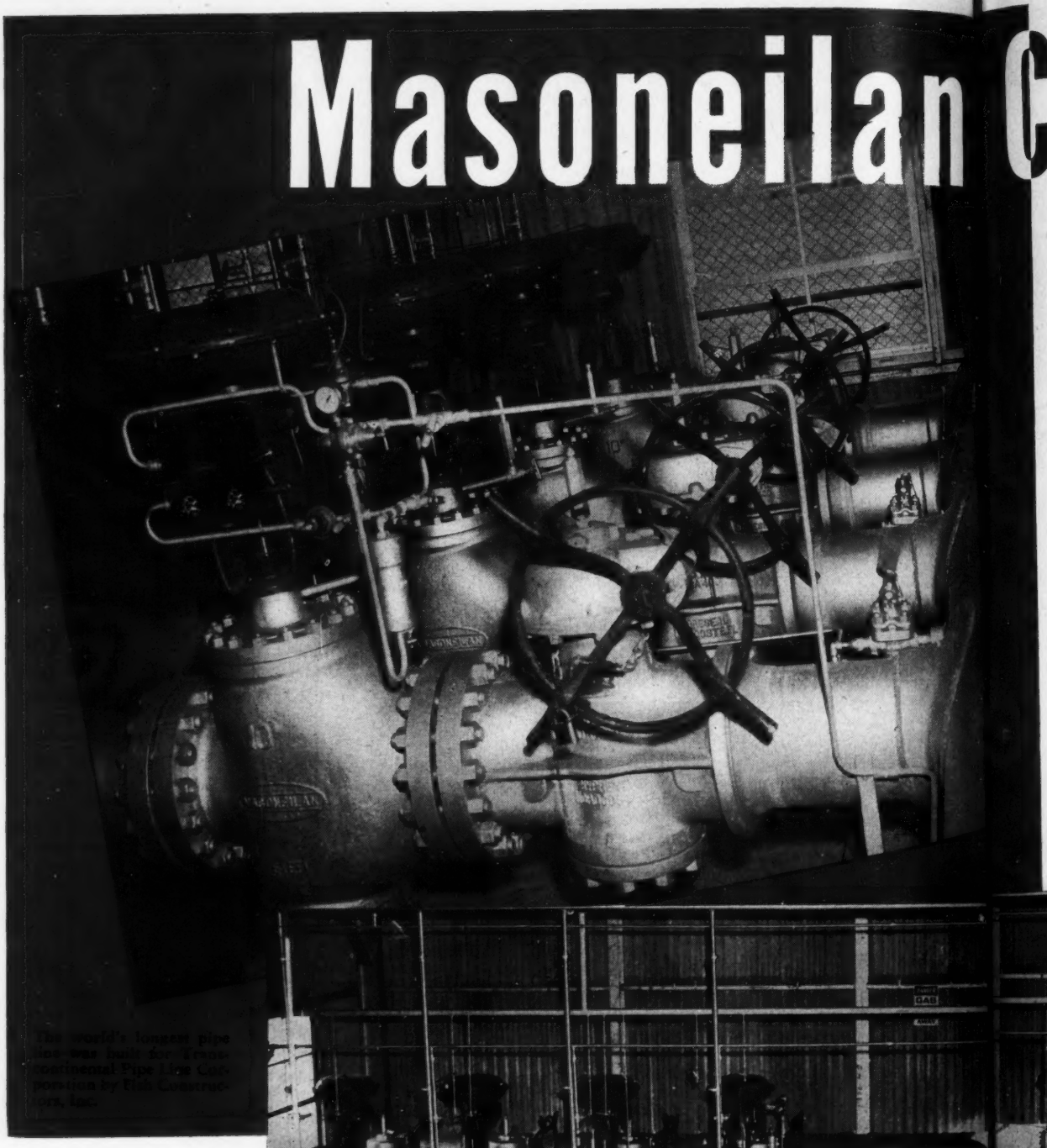
The above photograph shows the extent to which SK Rotameters are used in the plant of Publicker Industries, Inc., Philadelphia, Pa., world's largest producers of commercial alcohol. All of the Rotameters shown on the panel are of the SK Universal Type and are used to measure fluid flow rates in the manufacture of commercial alcohol. Numerous sizes are represented since capacity requirements vary considerably.

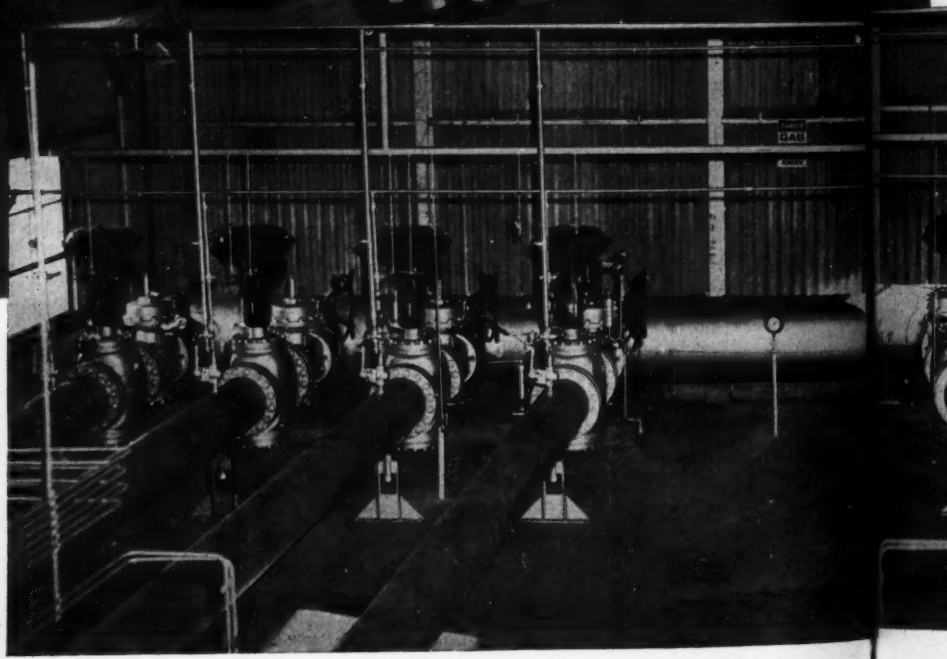
SK Universal Rotameters are available from stock. For detailed information request Bulletin 18-*RB.*

SK Flow Indicators, designed to permit visual inspection of flow in a pipe line, can prevent damage to expensive equipment by indicating to observer whether or not a fluid is flowing. *For information on the many types and sizes of SK Flow Indicators available, request Bulletin* 18-*W.*



Masoneilan C





Illustrated are Masoneilan 10″ Control Valves, Pressure Controllers and Positioners controlling pressure to low pressure header at Manhattan Regulator Station on the east bank of the Hudson River, adjacent to George Washington Bridge.

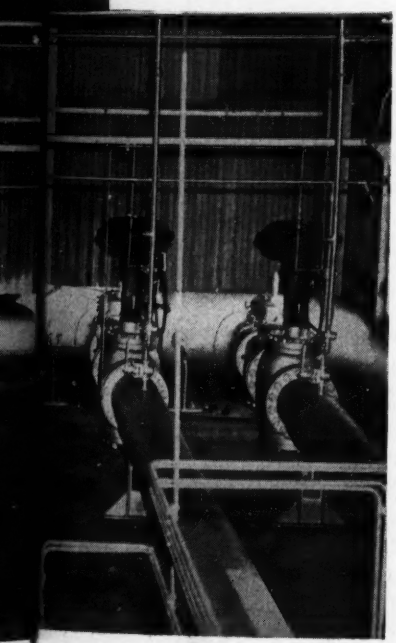
Control Valves

at Manhattan Terminal of Transcontinental Pipe Line

Deliver New York City's First Natural Gas

After flowing three to four days through over 1800 miles of 30-inch pipe, 250 million cubic feet per day of Texas-Louisiana natural gas is delivered to the eastern seaboard for distribution in New York City . . . the longest pipe line in the world is in operation.

Masoneilan 10-inch Series 10,000 Control Valves, operated by Masoneilan Model 2707 Pressure Controllers and Masoneilan Series 7400 Positioners, control the gas pressure at the Manhattan and Linden, N. J. terminal stations. A portion of the gas controlled by these Masoneilan Valves at the Linden terminal is destined for eventual distribution to New England.



The preference for Masoneilan Control Valves among pipe line builders and operators is recognition of quality which has been endorsed by the selection of Masoneilan Valves for the major pipe lines of the world.

If your responsibilities include control valve selection for *any* industrial use, compare Masoneilan Valves with any others.

Quality Characteristics Make Masoneilan Control Valves Outstanding

MASON-NEILAN REGULATOR CO.

1210 ADAMS STREET, BOSTON 24, MASS., U.S.A.

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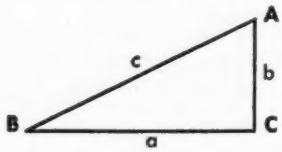
LITTLE THINGS ARE IMPORTANT!

Arma Electrical Resolver



Making important things little is a militarily vital objective of the accelerated engineering activity which characterizes Arma. Making them little and interchangeable and more accurate... all at the same time.

An example of advancing miniaturizing accomplishment is the new lighter, more accurate and interchangeable Arma electrical resolver. This is one of the computing components that replaced a formidable aggregation of gears, bearings and slides previously used in fire-control equipment to solve the trigonometric functions. It is the "thinking" mechanism in modern military instrumentation which solves such gun-laying equations as $a = c \sin A = c \cos B$ instantaneously.

The mechanical resolvers of World War II have since given way to the electrical. Application of the new miniature Arma electrical resolvers to the needs of all the Services is widening as rapidly as accelerated engineering can push it. This is another way Arma engineers work to help make America safe against those who wish to destroy it.

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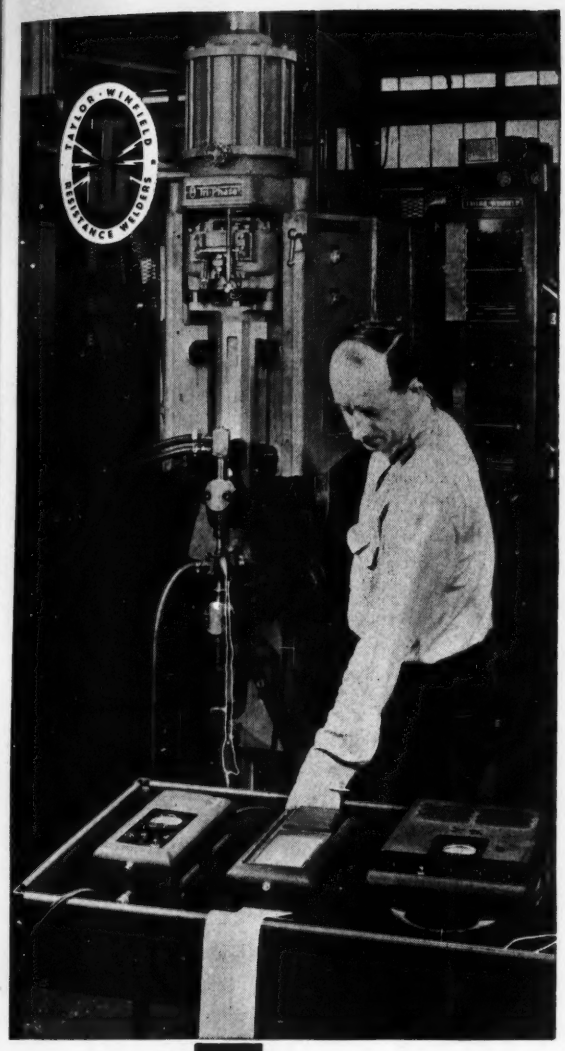

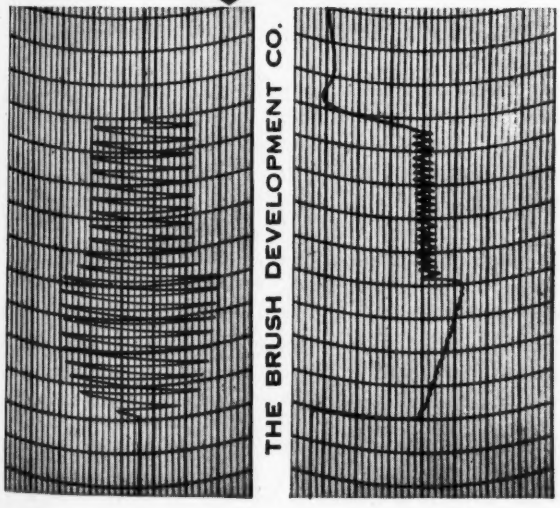

Put it in writing with a
BRUSH RECORDING ANALYZER

welding specifications a problem?

BRUSH ANALYZER RECORDS WELDING CURRENT AND TIME EXACTLY

● The Taylor Winfield Corporation, manufacturer of resistance, spot, seam, and butt welders, makes sure of correct current and timing calibration on each spot welder before shipment.

While a sample weld is being made, a Brush Analyzer records amplitude and timing of both input current and welding current on the same chart. By observing the wave shapes, Taylor Winfield inspectors calibrate controls quickly and surely. Production time is saved, and correct results assured.

Maintaining welding specifications is difficult with "rule-of-thumb" adjustment, particularly on metals such as aluminum. Brush Analyzers can give you written proof of welding currents, or of electrode pressures.

Investigate Brush instruments for studies of d-c or a-c voltages or currents, strains, displacements, light intensities, temperatures, and other static or dynamic conditions. Write for information. The Brush Development Company, Dept. A-5, 3405 Perkins Avenue, Cleveland 14, Ohio, U. S. A. *Canadian Representatives:* A. C. Wickman (Canada) Limited, P. O. Box 9, Station N, Toronto 14, Ontario.

Chart of welding cycle on Taylor Winfield welder shows 60-cycle A-c input current at left, D-c welding current at right. This Brush Analyzer consists of A-c amplifier, D-c amplifier, direct-writing oscillograph.

THE *Brush* DEVELOPMENT COMPANY

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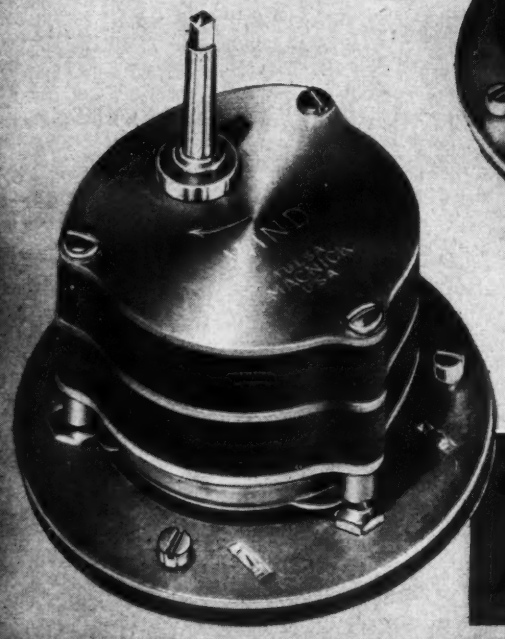
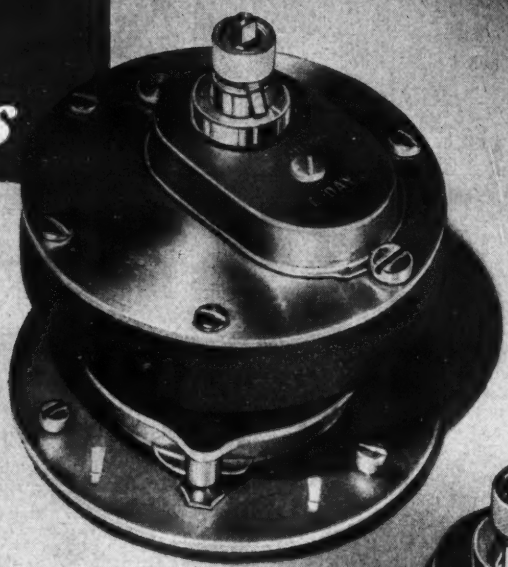
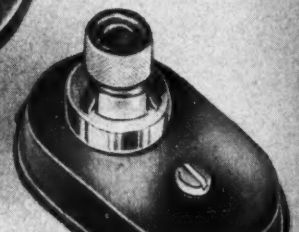
ELECTROACOUSTICS • ULTRASONICS • INDUSTRIAL & RESEARCH INSTRUMENTS

Mighty Midgets



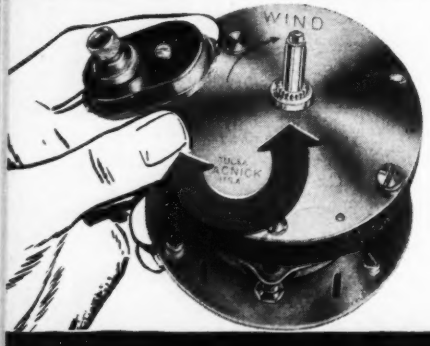




SHOWN ACTUAL SIZE

Left to right: Rockwell 24 hour wind and 8 day wind midget mechanical drives with rotation-converting Turret that, on the eight day model, permits one basic drive to be adapted to as many as 11 different speeds.

dependable, convenient drive for Meters, Controls, Recorders



THE TURRET ON TOP *does the trick!*

The above illustration shows how Turrets lock onto the chart arbor of the eight day model to change rotation speeds. The eight day drive is basically 24-hour rotation. Turrets are available for chart rotation times of 2, 3 4, 6, 8, 12 and 48 hours; 3, 7 and 8 days.

THE **MOST** CHART DRIVE IN THE **LEAST** SPACE

Rockwell Midget Chart Drives fill the need for compact, powerful mechanical drives in instruments where space is at a premium. They are strongly constructed with cases of die cast aluminum, gears mounted in phosphor bronze bearings and an escapement case made of stainless steel and clear plastic. This escapement snaps into place without tools and is readily replaceable.

Rockwell Midgets wind through the chart arbor. They snap into a separate mounting ring only 3¼" in diameter which may be positioned on bosses or adaptors to fit any instrument case.

This combination of small size, versatility of application and precision construction makes Rockwell Midgets the most economical drives to use. It will pay you to specify them in instruments made by any manufacturer.

ROCKWELL MANUFACTURING COMPANY

PITTSBURGH 8, PA.

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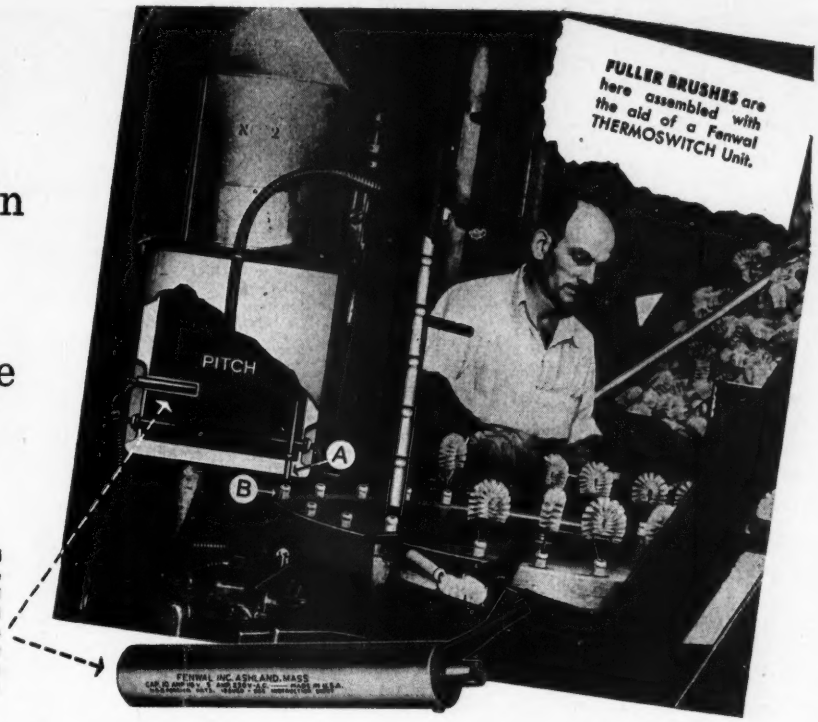
ROCKWELL CHART DRIVES

Multi-Purpose Thermostat solves problem in Fuller Brush assembly—prevents damage to machinery, motor



INVERSE CARTRIDGE THERMOSWITCH UNIT #17001 which closes on temperature rise is inserted in well inside of pitch tank and connected in series to starting switch and magnetic contactors. Machinery operates only when pitch has reached the preset temperature that assures fluidity. It then moves through automatically operated spout (a) into hollow brush handle (b).

When vegetable brushes are assembled at the Fuller Brush plant, a pitch-like sealing compound is poured into the hollow handle of the brush. The brush is then inserted in the handle and completed brush moved on to packing room.

Trouble-point in this procedure was the sealing compound. If it were not heated to a fluid state before machinery was started, automatic spout was broken and motor burned out.

A low-cost Fenwal THERMOSWITCH Unit averted this stoppage by continually, *accurately* controlling the operation of the motor. Electric motor cannot now start until the compound has reached the desired temperature. Thus damage to machinery as well as motor is prevented.

Easy-to-install, easy-to-maintain Fenwal THERMOSWITCH thermostats solve all types of control problems in industry. Their activating control element is the single-metal shell that expands or contracts *instantaneously* with temperature changes, making or breaking the totally enclosed electrical contacts. It is this unique principle that enables THERMOSWITCH Units to effectively control *many* variables where heat is a factor.

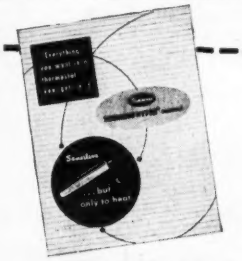
Mail the coupon today and find out how Fenwal THERMOSWITCH Controls can help you in your own processing.

Fenwal

THERMOSWITCH®

The Precision, Multi-Purpose, Thermostat Control

SENSITIVE...*but only to heat*



FREE!

Get this bulletin . . . see what Fenwal THERMOSWITCH Units can do for you. *Just fill in coupon and mail ...no obligation.*

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- ☐ Pressure Control (by controlling vapor temperature)
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OTHER (Please fill in your special requirements)

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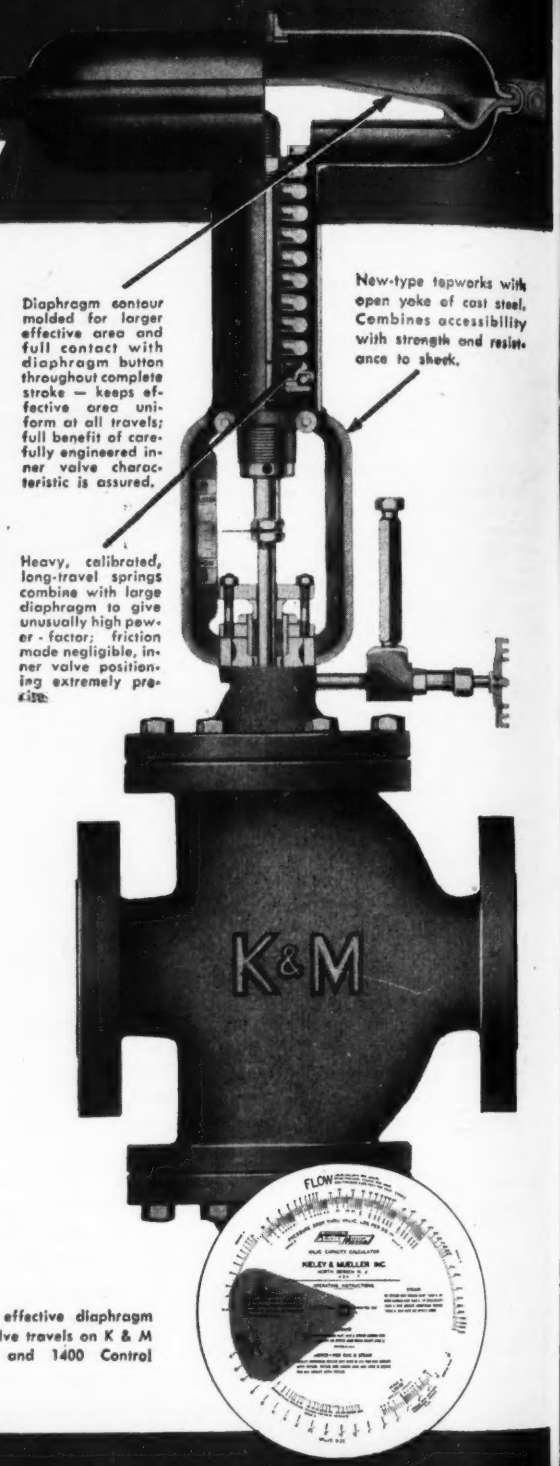
.....

K & M The Control Valves with

GREATER POWER *for* GREATER ACCURACY

The Diaphragm Motor of the far-advanced K & M Control Valve is designed for the more exacting needs of modern process industries. An unusually high power-factor is obtained by the carefully-engineered relationship of large effective diaphragm area and heavy, calibrated spring; friction is negligible, inner valve positioning more precise. The diaphragm is specially designed for constant affinity with the button contour; this assures a uniform effective area throughout the complete valve stroke, thus more uniformly accurate control. The unusually large area of the diaphragm in relation to the valve size also helps assure more precise control.

K & M motors are available for direct action or reverse action without change in effective area or stroke.


Diaphragm contour molded for larger effective area and full contact with diaphragm button throughout complete stroke — keeps effective area uniform at all travels; full benefit of carefully engineered inner valve characteristic is assured.
New-type topworks with open yoke of cast steel. Combines accessibility with strength and resistance to shock.
Heavy, calibrated, long-travel springs combine with large diaphragm to give unusually high power-factor; friction made negligible, inner valve positioning extremely precise.
K&M
FLOW
KIELEY & MUELLER INC.

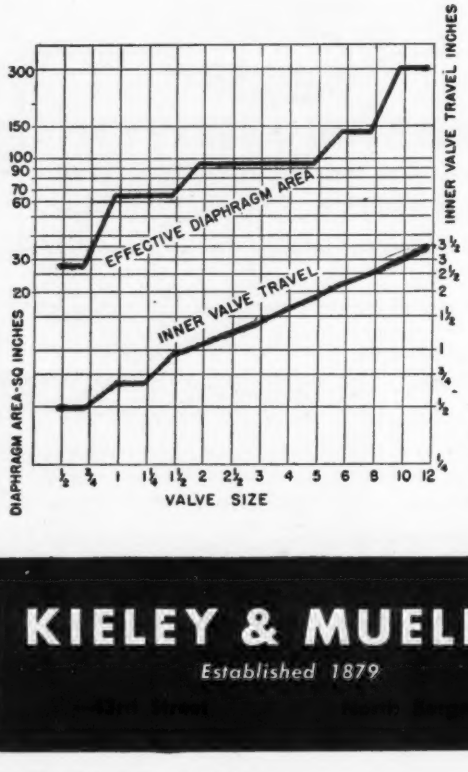


Chart shows effective diaphragm areas and valve travels on K & M Series 1200 and 1400 Control Valves.

KIELEY & MUELLER

Established 1879

NEW PROGRAM CONTROLLER AS EASY TO ADJUST AS YOUR RADIO

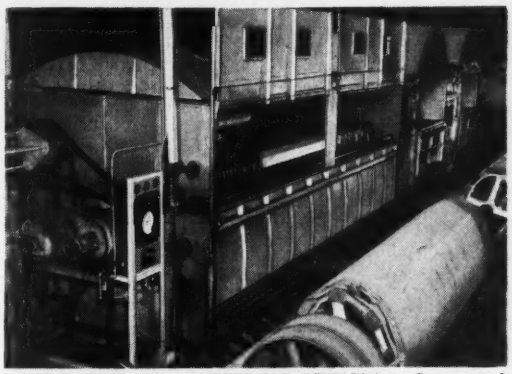
Gotham, first to bring you a completely enclosed Program Controller, was also first to conceive of all adjustments from the outside of the case. With the new Gotham Program Controller, incorporating the new outside adjustment principle, you can set the time, rate of rise, hold, and rate of cooling as easily as you tune your radio. You can control either temperature or pressure vs. time. Write for Catalog No. 500 describing in full the construction, operation, and application of the new Gotham Program Controller.

GOTHAM INSTRUMENTS

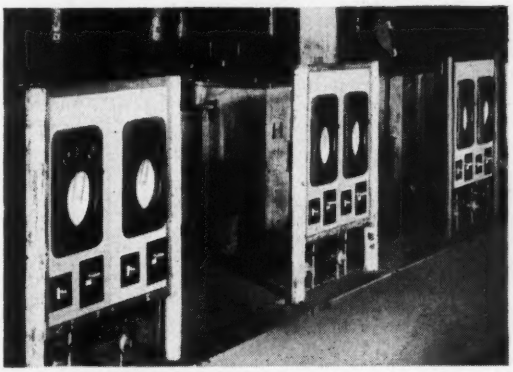
Keep Everything Under Control With Gotham

60 Gotham PC's at Botany

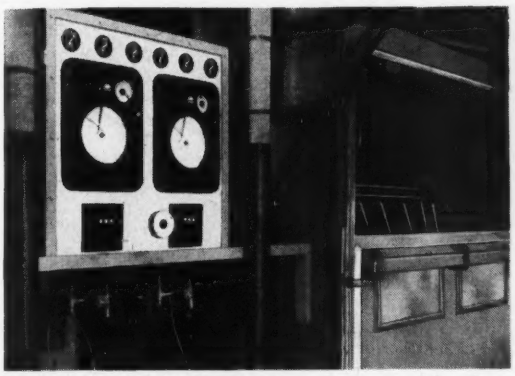
Over 60 Gotham Program Controllers are in use by famous Botany Mills, Inc., Passaic, N. J.



ONE OF WORLD'S LARGEST DYE KETTLES is at Botany and its dyeing cycle is supervised by Gotham Program Controller. Program control helps to maintain uniformity of the color.



12 TOP DYE KETTLE program controller units by Gotham are installed at Botany. Program control enables Botany to adjust quickly the variable time cycles required to get level dyeing.



EACH OF 48 DYE KETTLES like this at Botany, used for piece goods, is individually handled by its own Gotham Program Controller.

Photos: courtesy of Botany Mills, Inc.

GOTHAM INSTRUMENTS
Division of American Machine and Metals, Inc.
Dept. 2, 233 Broadway, New York 12, N. Y

Please send me a copy of your latest catalog and more information about Gotham ☐ Program Controllers ☐ Timers ☐ Recorders ☐
Have your man call. No obligation, of course.

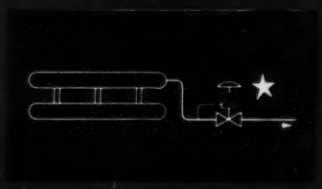
Name _____ Title _____

Company _____

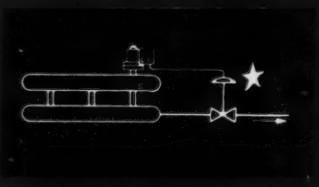
Address _____

City _____ Zone _____ State _____

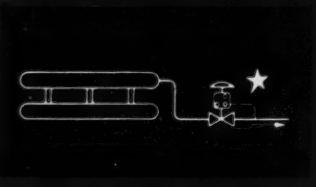
. . . the INDUSTRY'S MOST VERSATILE DIAPHRAGM CONTROL VALVE



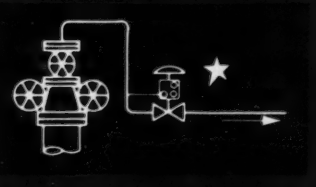
BACK PRESSURE VALVE



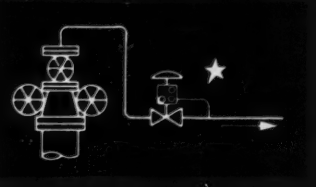
SEPARATOR OIL VALVE



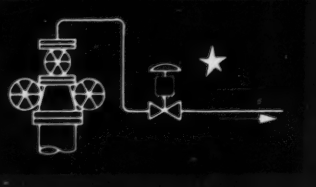
REDUCING VALVE



PRESSURE INTERMITTER

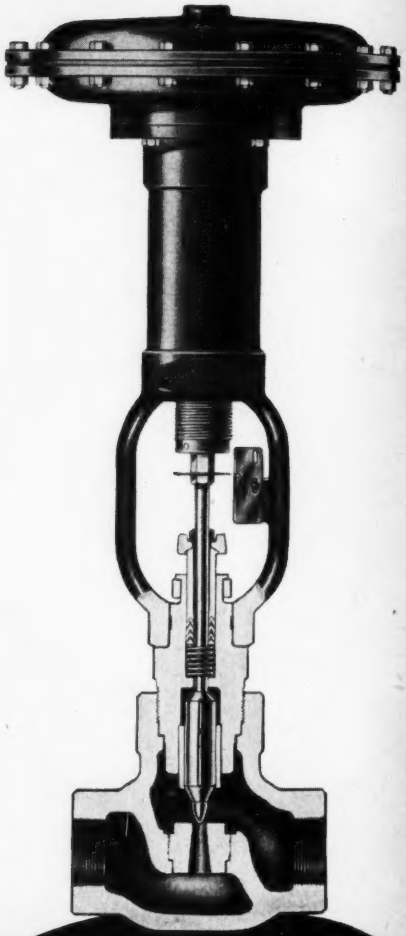


HI-LOW SAFETY VALVE



TIME CYCLE INTERMITTER

FISHER GOVERNOR CO.



FISHER® TYPE 57T-D

Fisher Type 57T-D is available in 3000 lbs. and 6000 lbs., globe or angle, cast steel bodies. Globe body sizes ½" through 2"; angle body sizes 1" and 2". Furnished with *Fisher Teflon V-Ring Packing* that requires no lubrication.

Write for complete information on Fisher Wizard Pilot and Time Cycle Intermitter.

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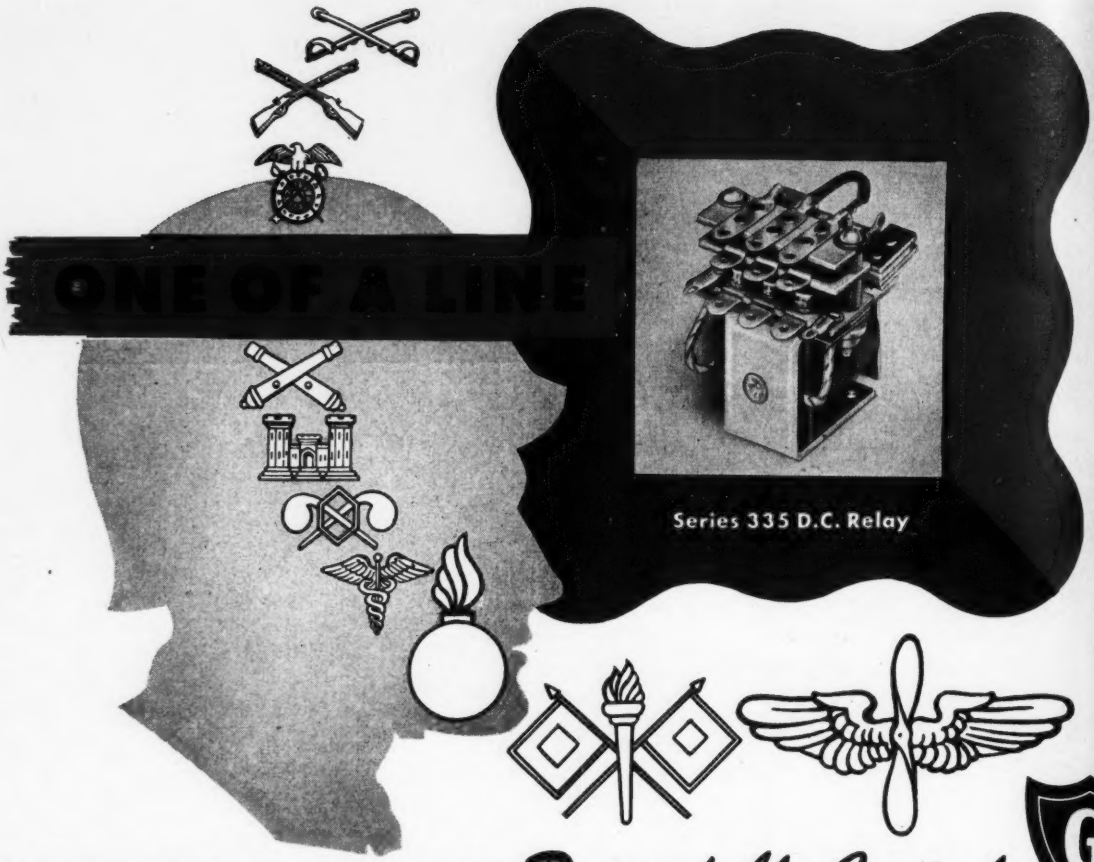

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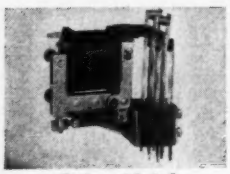
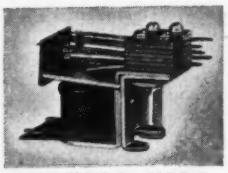
NEW CATALOG on Hermetically Sealed Guardian Relays with various containers is yours for the asking, cost-free.

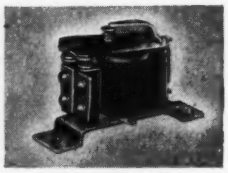
A.N. CONNECTOR PLUG HERMETIC SEALED CONTAINER



Series 30 A.C.

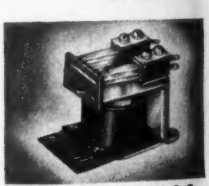


Series 210 A.C.—215 D.C.



Series 220 A.C.

Series 595 D.C.



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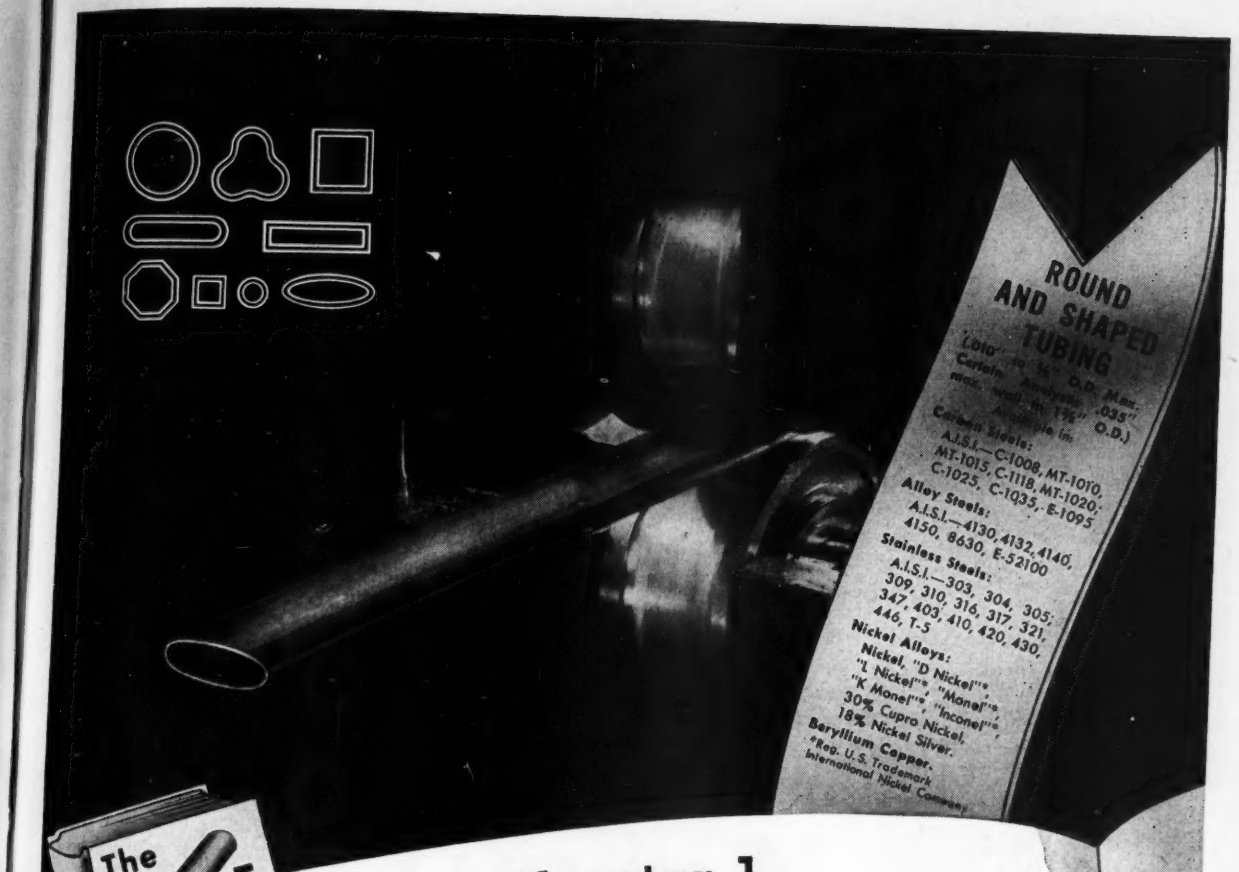
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The HOLE Story —by— Superior

Chapter 1

Shaping a Heart for a Pressure Gauge Requires "Technology in Tubing"

Soon after the tube pictured above comes off the shaping roll, it will be processed into a Bourdon tube, the heart of a pressure gauge, by one of our customers.

The design of a gauge movement and the skill of the gauge builder have a bearing on its accuracy. But nothing can compensate for an irregularly responding Bourdon tube.

That's where Superior comes in. The metallurgy of the tube, its dimensional precision and physical characteristics are all critical . . . and all are rigidly controlled at Superior.

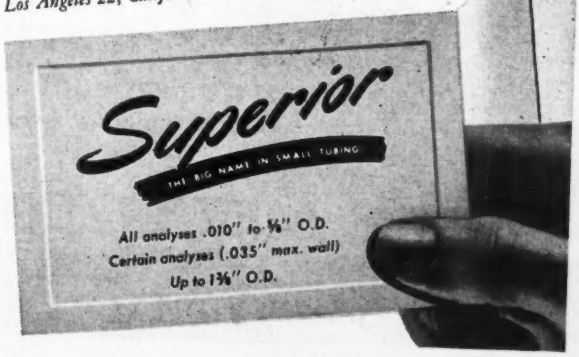
This rigid control is applied to all tubing produced by Superior.

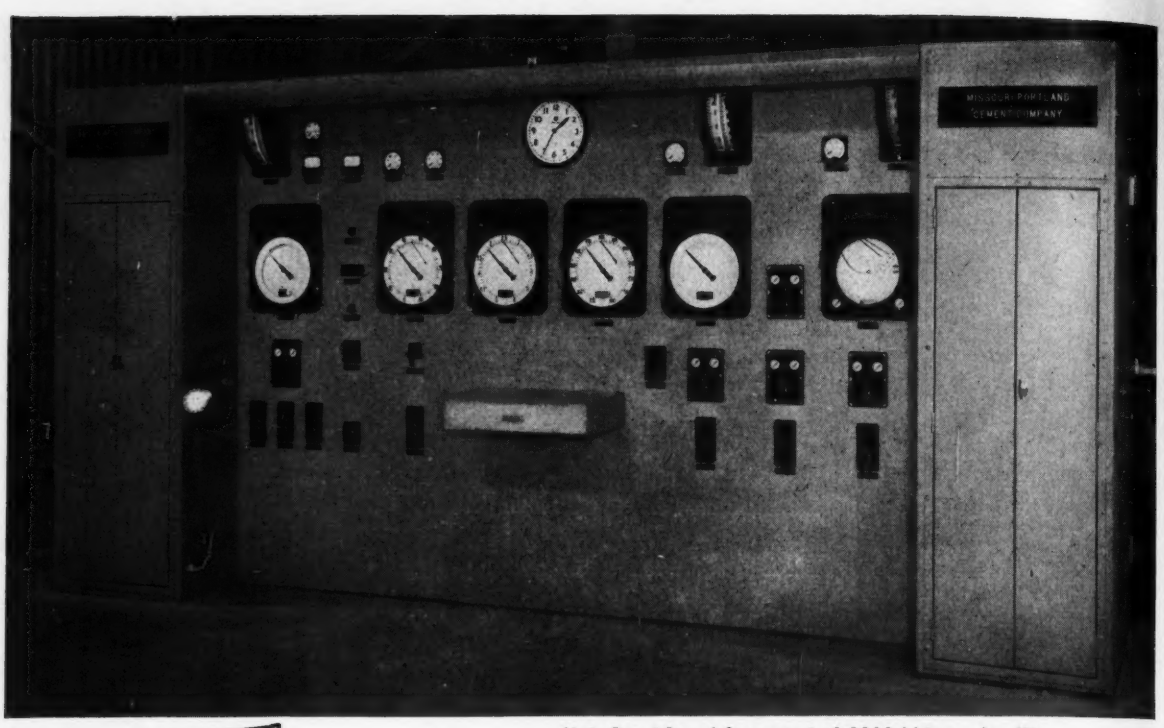
For example, in the production of seamless steel tubing for hydraulic applications, industry standards permit a carbon range of .08 to .18%. This range is not good enough for Superior. Aiming for a carbon content of .12%; Superior Hydraulic Quality tubing is always held to .15% maximum. This insistence on adherence to strict standards applies equally to dimensional tolerances.

Superior produces tubing to rigid specifications year in and year out. We have the engineers, metallurgists, research, production and test facilities that it takes to draw the highest quality small tubing in the widest variety of analyses.

You can call this combination of facilities, men, methods and machines "know-how" . . . or you can call it experience. But whatever you call it the result is always fine small tubing to do a better job for you. SUPERIOR TUBE COMPANY, 1968 Germantown Avenue, Norristown, Pa.

West Coast: Pacific Tube Company, 5710 Smithway St., Los Angeles 22, Calif. UNderhill 0-1331.





Main Panel Board for control of 3000 bbl per day Kiln at Missouri Portland Cement Company, St. Louis, Missouri.

3 Ways Better

...Bailey Control for Rotary Kilns

Bailey Control for Rotary Kilns gives you better performance three ways:

1. Economical Operation
2. Uniform Quality of Product
3. Reduced Maintenance

These are advantages which can be achieved when all phases of kiln operation are coordinated to work together as a team. Here's how Bailey Kiln Control can help you get all three.

ECONOMICAL OPERATION

With Bailey Combustion Control you can be certain that you are getting maximum product for every unit of fuel you burn. Bailey Control closely guards the Fuel-Air Ratio, Hood Draft, Fuel Feed, Clinker Cooling and the Temperature of Air for Combustion.

UNIFORM QUALITY OF PRODUCT

Bailey Instruments and Controls can help you achieve a uniform high grade product. Measurements of temperatures, kiln speed, combustibles content, and oxygen content can be transmitted to recorders on centrally located control boards like the one shown. There is no sacrifice of accuracy or speed of response. High temperature alarm contacts may also be provided with Bailey Pyrometers as a further aid in achieving optimum uniformity of product.

REDUCED MAINTENANCE

By maintaining uniform temperatures and excess air conditions in the kiln, Bailey Controls help to reduce to a minimum costly refractory repairs and wear and tear on auxiliary equipment.

Bailey Meter Company has a staff of engineers who are experts in the control of rotary kilns. Assure yourself of optimum kiln performance. Let one of these men help plan your Kiln Control System. P-22

BAILEY METER COMPANY

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Controls for Processing

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PRESSURE
% OXYGEN
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FLOW
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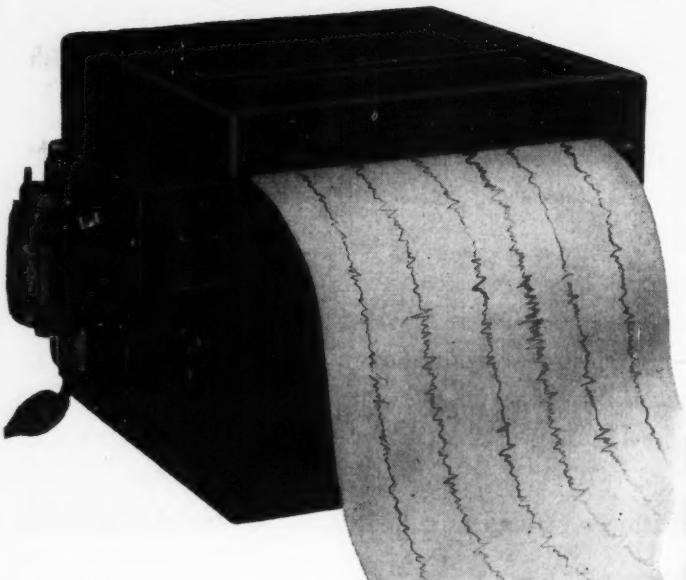


Type 133 Amplifier

drift-free d-c recording

- SPEED
- TEMPERATURE
- PRESSURE
- VIBRATIONS
- POSITION
- OTHER VARIABLES

check these exclusive Dynograph features

Pen Deflection Linearity of 1% with pen response of 1/120th of a second.

Sensitivity of 150 microvolts d-c per centimeter of pen deflection.

Stability and drift-free operation through a special chopper type amplifier.

No extra equipment needed with reluctance type pick-ups.

True Differential Input obtained through special transformer coupling.

Offner Electronics Inc., the original manufacturer of precision, direct writing oscillographs, now offers to industry the Dynograph Recorder—a direct writing, high speed oscillograph with microvolt d-c sensitivity.

Operating at approximately 100 times the speed of other industrial recorders with comparative sensitivity, the Dynograph simultaneously records many variables formerly recorded only by photographic means.

Now you can obtain a precise record of transients in the operation of various equipment through a ruggedly built, easy to maintain, versatile d-c recorder—the Dynograph.

Write Today for Bulletin L-311—Complete Specifications and Construction Details of the Dynograph

OFFNER ELECTRONICS INC.

5320 N. KEDZIE AVENUE **CHICAGO, 25**

Instruments

Welcomes

New Managing Editor

IT is a pleasure for *Instruments* to announce that Milton Howard Aronson is joining its staff as Managing Editor. Mr. Aronson brings to *Instruments* his energy, ability, and diversified experience in the fields of industrial instrumentation, electronics, writing, and education.

Mr. Aronson graduated in 1939 (B.S. in Physics) from Carnegie Institute of Technology, where he earned many scholarships and was elected to Tau Beta Pi, Phi Kappa Phi, and Sigma Xi.

From 1939 to 1942 Mr. Aronson was an instrument engineer at the Clairton (Penna.) plant of Carnegie Illinois Steel Corporation. As this plant has blast furnaces, open hearths, rolling mills, soaking pits, coke ovens, tar plant, distillation columns, and boiler houses, Mr. Aronson worked on all types of industrial instruments—pneumatic, mechanical, electrical and electronic.

He installed, calibrated, and serviced many of the plant's indicators, recorders, and controllers. Under Joe Keller, who is well-known to Western Pennsylvania instrument men, he contracted the "virus instrumentitis" that has brought him finally to our staff. It was also in this pre-Pearl Harbor period that he became a charter member of the Instrument Society of America, then called the American Society for Measurement and Control.

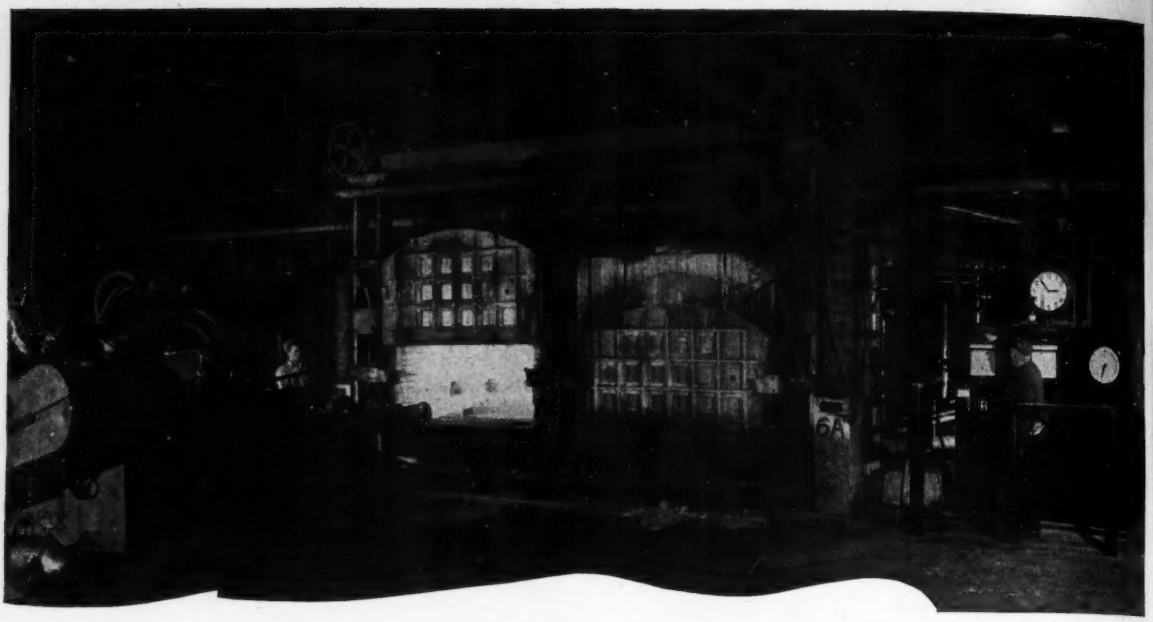
In 1942 Mr. Aronson joined the Instrument Section, Research Division, of the Naval Ordnance Laboratory, White Oaks, Md. His work was electronics research and development. He developed many original electronic circuits and has several patents associated with the instrumentation problems of the laboratory, including high-impedance voltmeters, counting circuits, feedback amplifiers, level-control circuits, electric-pen recorders, transient-peak voltmeters, and power supplies. As a project leader he had full responsibility for a project that included the telemetering and recording of high-speed transients.

Mr. Aronson left the Naval Ordnance Laboratory in 1947 to become a writer in the Naval Reserve Training Publications Center, Washington, D. C. After writing three excellent texts on Fundamental Naval Electronics, he was made head of the Electronics Section. As head of the Section he organized, coordinated, and supervised his staff of eight technical writers, two editors, and clerical help.

His Section has produced textbooks and training manuals on basic electronics, communications equipment, search radar, fire-control radar, sonar, radiac (radioactivity) equipment, infrared equipment, guided missiles, aircraft electrical systems, military television, and others. An important function of his Section was the preparation of home-study correspondence courses based on the subject-matter in the textbooks. His books and courses have received special commendation for their technical and educational excellence.

In this age of rapid technological progress, continuous study is required to keep abreast of developments. Mr. Aronson has studied advanced mathematics, advanced calculus, and ultra-high-frequency techniques at the Graduate School of Maryland University. He indulges his hobbies—woodworking, audio-system engineering, and television design—in a home workshop that is completely equipped with woodworking and electronic equipment.

Mr. Aronson has always earned both the respect and affection of his associates and superiors. He is happiest when serving others and will help make *Instruments* an ever-increasing source of help and pleasure to its thousands of readers.



This New Controller Says "Hurry Up, Furnace!"

WITH production reaching toward all-time highs, this new P.A.T. 50 Control already is helping many key plants increase the output of their furnaces. Here's why:

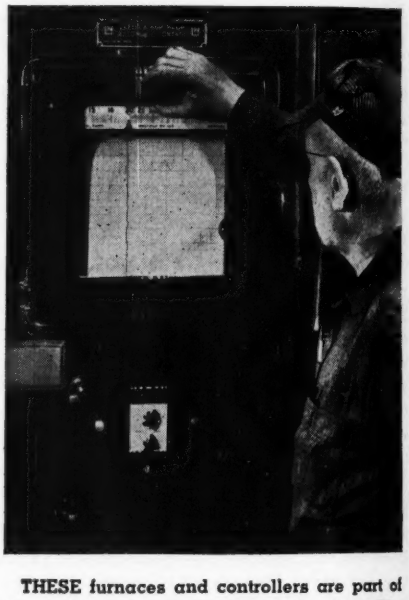
This Control has something that's brand new in proportional, electric controllers. Called "rate action," this feature enables the Controller to act on the *speed* of swings in furnace load, as well as on their size and on the length of time they persist. Thus, if temperature changes gently, it is gently nudged back into line. But if it starts off vigorously—as when the furnace door is opened—P.A.T. 50 reacts vigorously. Then, when the change has been headed off, the Controller starts to back away. But "putting on the brakes" it brings temperature in line smoothly and rapidly.

Thus, "Rate Action" increases production because it reduces the length of time a furnace is off temperature.

Also, Proportioning and Reset Actions are more responsive than before. These two components stop the normal temperature swings which are started by changes in the size and permanence of the furnace load. Even without rate action, these increases would enable P.A.T. 50 to do a better-than-ever job. With rate action, results are superior to any previous electric control.

The News is in the Control Unit at bottom of panel shown at right. Earlier installations can be converted to P.A.T. 50 by replacing the Unit and making slight changes in the Controller.

For details, contact our nearest office, or write us at 4955 Stenton Ave., Philadelphia 44, Pa.



THESE furnaces and controllers are part of the slab-heating equipment with which The Timken Roller Bearing Company, Canton, O., conditions high-alloy steels for rolling. The Timken Company has used many earlier L&N Controllers. They find P.A.T. 50 is a further step forward, not only in guarding quality, but also in increasing production by shortening the off-temperature time.

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Instruments THE MAGAZINE OF Measurement and Control

M. F. BEHAR, Editor

Classifications: KEYS *to* KNOW-HOW *in* Instrument Work

By M. F. BEHAR

To the reader whose student days are over, this article may provide a key to greater success in whatever kind of instrument work he is doing. This key is not new. It appeared some three thousand years ago and was perfected before this century. Most people call it "system" or "the scientific method" or "philosophy" or "organization" or "mental filing system"—or even "knowing all the answers" (which refers to the result of using the key, not to the key).

The official name of this key, Methodology, suggesting ivory-tower academies, conceals two facts: (1) that it is a lot of fun; (2) that it is used by garage mechanics as well as by Research Directors when they solve problems.

For erudite GENERAL dissertations on Methodology as a mental discipline, go to a library with well-stocked Philosophy shelves. The following is simply a popular SPECIFIC account, whose purpose is not to teach a subject but to convey an attitude.

Methodology is not a memory course or mind-training: the title on this page summed it up by stating that classifications are keys to know-how: A key is no good if it does not fit; and only the right kind of classification can set free a particular know-how and make it usable. Methodology consists partly in making keys that fit. It is practiced unconsciously by everyone who thinks instead of emoting: quite often by persons with methodical minds; only occasionally—but in some cases more effectively—by persons whose minds are not naturally methodical. It need not be practiced by—and would be of little help to—butchers, bakers and most modern occupational groups. It appears to be most useful to workers in NEW industrial and scientific fields. It appears to be more useful to Instrument Men (from apprentices to department heads) than to any other scientific and technical workers. Obvious reason: the formidable complexity of modern instrumentation. Fortunately, the Instrument Man, whether his mind is or is not naturally methodical, has already proved—by his choice of job—that he has what it takes to apply methodology to his own work: a healthy curiosity.

The reader has benefited from the results of Methodology ever since his childhood. When he went to school he noticed that all human knowledge, as taught there, was divided into reading, writing, grammar, arithmetic, music, history, natural history, geography, physical culture and hygiene, etc. His first acquaintance with one of the great classifications probably was when he learned that the Empire of Nature is divided into the Kingdoms of Animals, Plants and Minerals. The reader may have been taught in high school that Aristotle (384-322 B.C.) arbitrarily set up these three kingdoms and that Carolus Linnaeus (1707-1778) organized them systematically for the first time, but he probably was not taught the method (Fig. 1) or the modern names of the subdivisions* of the kingdoms. The fact is that seldom if ever did one man in one lifetime create and develop as useful a filing system as this one. The whole organization of modern natural science has been built upon the Linnaean foundation. Today, of course, his Mineral methodology is a mere historical curiosity, but it was to classifying and naming all the then-known animals and plants that he devoted his life. His binomial nomenclature stands intact: every previously-known or newly-discovered animal or plant has two names: for its genus and for its species. Thus the "American jaguar" has many names in various States and in Latin-America, but only one name (*Felis onca*) throughout the whole world. Linnaeus made good keys —keys that still open doors today.

At this point the reader may be saying to himself, "So what?"

So this: In the field of Measurement and Control there are tens of millions of possible combinations of measurables, of effects, of applications, of objectives and purposes, of methods, of physical components, of functions, properties and responses of components and systems. Only a start has been made in organizing this enormous realm: past work is a molehill compared to the mountain of work that remains to be done. Even if this science and art were frozen as of this moment; even if no instrument manufacturer were to bring out new models; even

*For the Animal Kingdom these are: Phyla; superclasses, classes, subclasses; superorders, orders, suborders; superfamilies, families, subfamilies; supergenera, genera, subgenera; superspecies, species and subspecies. (These are the modern American names and arrangement in which the "supers" and "subs" are not essential but convenient.)

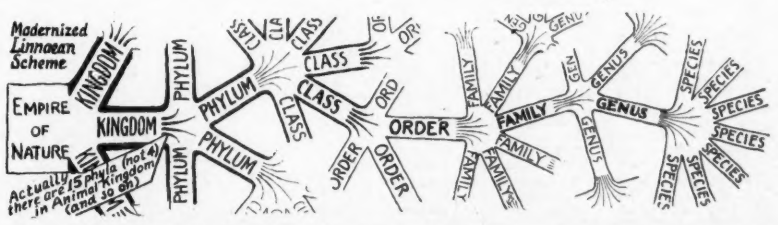


Fig. 1. Sketch of one modern modification of the great scheme devised and carried out by Linnaeus. In this sketch, only the number of Kingdoms is correct; the numbers of subdivisions in all other subsequent branchings are incorrect except for possible accidental coincidences. Moreover, between the kingdoms and the genera, authorities differ on the exact numbers of branches to be recognized and on their names and attributes.

if no more books or articles on measurement or control were to be published —millions of decisions would still be open for each Instrument Man: millions of possible solutions to his daily problems, all solutions based on EXISTING methods and things, none involving Invention (in the true sense—not the mere legal sense). And since Instrumentation is not frozen but growing like a healthy youngster, the millions of possibilities pile up. The reader being an Instrument Man, he knows that for each problem there is only One Best solution. Of the millions of possible solutions for YOUR problems, can you find the optimal solution each time? No human being can do it each time, because it never is like COMPUTING the one correct solution of $x = 3a^2 + 5$ when $a = 2$. But your intuition usually tells you that there is One Best Way of finding the optimal solution each and every time. This One Best Way is not always an easy road: it seems to be barred at every turn by a door of your previous patterns of ideas. The master key that fits these doors and smooths the way is Methodology. Now you may be wondering: "Why select the Linnaean scheme as the model, instead of a classification of electrical or chemical or mechanical or optical things and methods?" One answer has been given: the aim of this article is not to teach a subject but to convey an attitude. Another answer is that no methodology is as suitable here as the Linnaean.* Still another answer is that the methodology closest to your work (that of Instrumentation) is a clumsy one-man job.† The final answer is that you—and you and you—are expected to do a better job after learning the rules of the game and practicing it.

The game is like bridge or chess: the rules are simple; the play is sometimes boresomely easy and sometimes excitingly difficult. Fig. 2 presents the rules graphically and shows how successive classifications—when properly done—MULTIPLY the advantages rather than merely adding them. At A is a formless heap of things and concepts. By studying them you discover enough similarities and contrasts to PLAN to divide the heap into five piles. If the heap be a "kingdom," the five piles are five "phyla." Now, if you name these five phyla, if you describe their attributes and if you arrange them in an orderly way, the result is a scientific list— a one-column "table" which, as shown at B, is not five piles but five "reservatories" or receptacles, here shown as shelves. Thus you have completed the PRIME DIVISION. If it is a Perfect Classification (to be explained later) every new member of the kingdom that is found or created in the future will be assignable to its rightful shelf. Each of the five shelves has to be of indefinite length to make room for the future members of its phylum; thus the shelves, though shown of equal length in the sketch, will be of unequal lengths.

Next, you discover, in ONE phylum, similarities and contrasts among ITS members, enabling you to divide THIS phylum into classes. Then, after examining each of the four other phyla, you divide it likewise into classes. The number of classes will vary because one phylum might have fewer than a hundred known members resembling one another, whereas another might have thousands of known and millions of potential members. Thus, there will not be any one-to-one correspondence of classes among all five phyla enabling you to line up the vertical partitions of all five shelves. On paper, you will not draw vertical lines intersecting all five prime divisions equally, but you will draw lighter horizontal lines dividing each phylum into classes. Thus the heighths of your phyla will vary. Then you will continue your classifications: for example, under most (not necessarily all) classes, you will list orders; under most (not all) orders you will list genera . . . and so on. This is the Linnaean scheme. It results in ONE "vertical table" of book-length.

You need never do such a long job in your work: in most cases the Prime Division and the first subdivision will be enough, if they be Perfect Classifications.

Your problems differ from those of the naturalist: they resemble those of biological specialists. For example, one studies the blood-types not only of the human species but of others; his specialty (hematology) cuts across the boundaries of genera, families, orders, classes and phyla. Another worker becomes interested in cells: cytology likewise cuts across these boundaries. But in physical science and technology—and in Instrumentation more than in any other field—this is not enough. What you do is to start a second time from the original heap—the kingdom—and work out a second PRIME DIVISION which must likewise be a Perfect Classification; next, one or more subdivisions. Assume now that you have established two phyla and exactly four classes in each phylum. If—and only if —both classifications are Perfect, the result is Sketch C in Fig. 2: five times eight, or forty bins, of INDEFINITE depths—of UNEQUAL depths. One bin may contain fewer than a hundred known species; another should provide for hundreds of thousands. This interlocking scheme is not the Linnaean scheme: it is simpler in some ways. For example, the establishment of subdivisions stops earlier because of the absence of imperatively determinant similarities ("homologies").

By now, you have the idea (you probably are saying, "I'm 'way ahead!'"), so that sketches D and E, and Figs. 4 and 5, all pertaining to your instrument work, will require little explanation—only some brief comments:—

Both sketches, D and E, represent the ever-growing body of information on: (1) the measurables; (2) the effects that are utilized in measuring instruments; and (3) the methods of measurement. At this time—mid-century—the possible combinations already run into the millions and every new

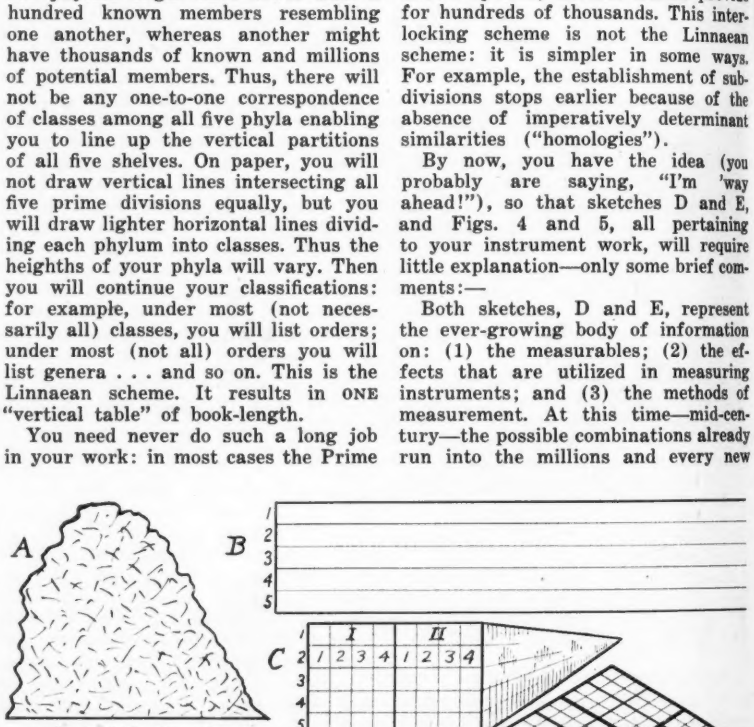


Fig. 2.

*Some readers who have studied philosophy will warmly agree: others will hotly disagree. Here are the main facts: The urge to classify originated in ancient times (cf. long dry passages of the Old Testament). Plato, Aristotle and the Peripatetics formalized it (the famous "categories"). After the fall of Rome, it was kept alive by the Semitic philosophers. In the 13th century Saint Thomas Aquinas produced his great classification of all human knowledge into Religion, Philosophy and Science. Scholastic Philosophy's classifications were based on dialectic rather than on observation and experimentation. Circumnavigating navigators and mathematical astronomers dealt one blow to Scholasticism; physical scientists and systematic biologists dealt another. The pendulum swung away from orthodoxy and tradition. Methodology itself was almost "worshipped" by some great philosophers and scientists, who were accused of "classifying everything and every idea except the Creator." Nowadays, the most famous universal Systems devised in the 17th, 18th and early 19th centuries are studied in both theological and secular colleges, but the historic controversies have turned up so many glaring defects in all of them that none of them could be offered here as a model. Of all the relatively "minor" schemes that did not include disputed ideas and dogmas, the Linnaean scheme is the most suitable for the present purpose.

†The approach that was decided upon in 1924 consisted in starting several classification systems simultaneously—one tangible system of filing cabinets, cross-indexes, etc.; and various conceptual systems. It was amateurish: many details had to be revised; and even the foundations which today stand unshaken and support lighthouses may need revision tomorrow. The first classification was necessarily imperfect from the start because it was like a new-born babe trying to describe what it is made of. It is imperfect in its latest form.

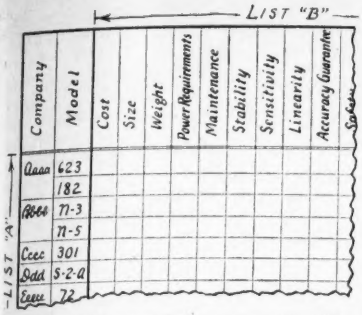


Fig. 3. Neither list being a true Classification, this sort of painstaking work, though METHODICAL to some extent (and hence much better than sticking a pin at random on a page of a classified directory) is not METHODOLOGICAL and hence is not certain to yield the One Best answer.

effect or element produces thousands of new "boxes."

The geometric figure D is a ONE-EIGHTH-ORDERED CUBE. It corresponds by analogy to mankind's information about living creatures before the advent of Natural Science. It is not utter chaos: it represents the BEGINNING of order. Most people think they know a subject when they have learned a mass of facts and have BEGUN to classify them. The knowledge of cooking picked up by the average housewife, who has NOT taken a modern ORGANIZED course in domestic science, might be a good example. In terms of instrument work, this one-eighth-ordered cube might represent the information on instrument elements possessed in 1920 by a competent professional man—say a metallurgist or a chemist—who had handled many kinds of measuring instruments in laboratories and plants for perhaps twenty years, but who had never taken time out to reflect upon the principles common to all measuring instruments.

Cube E shows an orderly scheme—not necessarily one of the particular schemes used in this book or in any other book, but ANY scheme of three interlocking "Perfect Classifications" which ANY user of measuring instruments can devise for his OWN purposes. This is not a flat injunction against using any of the classificatory schemes in this book or in another book: These already-worked-out schemes no doubt serve the needs of most readers. But the purpose of this Section is to induce each individual reader to learn the art of making his own master key for solving his own problems. A prerequisite is that you be skeptical of ALL classificatory schemes invented previously (unlike the mass of your fellow-workers who accept uncritically everything they read in technical books) and will discover that it's lots of fun to bring order out of chaos—that it's lots of fun even to improve upon previous schemes when you do not happen to be the first organizer to come upon a scene of chaos. As will be explained below, few classifications are perfect; most can be improved upon. So in cube E the names of the divisions and subdivisions have been left blank and the drawing merely suggests how it's done.

This cube represents an ideal, for all of its three sides are bounded—which means that each of the three classifications is a perfect one not only in its main divisions (roman numbers) but in its secondary divisions and (on the right-hand side) in its tertiary divisions.

Note that when there are three interrelated or interlocked classifications, the following results are progressively accomplished:

(1) Awareness that there are three interrelated lists to be classified transforms a formless heap into the beginning of a geometric figure: it creates one of the eight corners of the future cube, as in D. At this stage the lengths of the three edges are indefinite, undefined, undetermined.

(2) Completion of one of the three classifications, by creating one table of categories (instead of a never-completed catalog) creates two corners: one of the twelve edges. This edge is definitely bounded. (See sketch B.)

(3) Completion of two classifications creates four of the eight corners and four of the twelve edges; it completely bounds one of the six sides. It results in the familiar "table" made up of rows and columns, like the face of C, which is the commonest form of presenting methodically-arranged information on paper.

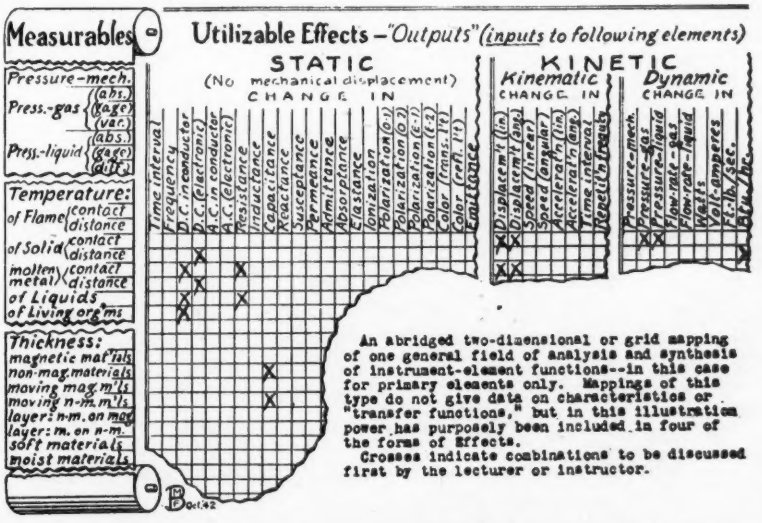
(4) Completion of all three interrelated classifications increases the number of column-and-row tables from one to two. It doubles the corners: from four to eight. It triples the edges; from four to twelve. But it does not merely triple the number of completely-bound faces: it immediately sextuples them: from one to six. The result—E in Fig. 2—is not merely two column-and-row tables: it is a "file of filing cabinets" or a "library of libraries" of interrelated information!

You need not strive at once for such an ideal. You probably will find it more enjoyable to devote some spare time to practice. Select any formless set or collection of things of interest to you that are related to one another in any way—even if they have only one thing in common; and give form and order to that list by discovering the similarities and contrasts and arranging the items accordingly, until you finally have, instead of a list of things, a list of categories—a Classification. It would be well to start with familiar items. Take, for example, household articles and classify them according to various schemes.

One scheme might be: (1) furniture, (2) clothing, (3) kitchen utensils, (4) table utensils, (5) sporting goods and toys, (6) books, (7) electrical appliances, . . . etc. A second scheme might be: (1) husband's things, (2) wife's things, (3) joint property, (4, 5 . . . children's). A third scheme might be: (1) metallic, (2) non-metallic, (3) composite. These three schemes, by the way, differ not only superficially but fundamentally. The first scheme is difficult to complete without naming the last category "Miscellaneous" or "Otherwise Unclassified." Moreover, there are uncertainties: are swim suits and golf sweaters clothing or sporting goods? The second scheme likewise presents uncertainties: whose property is the Sunday comic section? The third scheme—as you intuitively know—is a Perfect Classification.

What is Perfect Classification?

First: It is of course a list—but not a mere list. It is organized on a rational basis. An alphabetical list, though "organized" in a narrow sense, is certainly not a Perfect Classification and probably not even a classification. This implies that the "field" or "set" or "collection" which is to be classified perfectly must be clearly visible—at least to the mind's eye. (In the foregoing exercise you knew what was meant by the "household articles" in your own home, but a child might include such things as garden tools and might exclude such things as large pieces of furniture.) This does not imply, however, that all members of the set are known—or even that all are knowable—at the time that the classification is constructed.



An abridged two-dimensional or grid mapping of one general field of analysis and synthesis of instrument-element functions--in this case for primary elements only. Mappings of this type do not give data on characteristics or "transfer functions," but in this illustration power has purposely been included in four of the forms of Effects.

Crosses indicate combinations to be discussed first by the lecturer or instructor.

Fig. 4. In practice (outside of the lecture room) an individual or a team will be concerned with such a small number of measurables that these may be listed and need not be fully classified. But the ways of measuring these few magnitudes are usually numerous. These ways (effects or methods) should be classified.

Second: In a technical sense it is a list—but a list of CATEGORIES, not of things.

(The word "category" is used because it conveys to everyone the idea of an IMPORTANT division. You wouldn't call different body styles of one make of car different categories—nor different yearly models, nor different makes: usage has taught you that they are *varieties* of the passenger-car *type*, in the automotive-vehicle *class*, the ultimate category being Transportation. To philosophers the Categories are the most important divisions of universal Concepts: the "modes of predication.")

Third: The categories must be COLLECTIVELY EXHAUSTIVE. In other words, every present member has been assigned or can be assigned to one of these categories; every future member will likewise be assignable to one of these established categories; and there never will be any need of establishing a new category.

Fourth: The categories must be MUTUALLY-EXCLUSIVE. Every present and future member belongs in one and only one of these categories.

The third and fourth requirements have often been given as the only two requirements of a Perfect Classification. This is permissible because they imply the first two requirements. Some authorities therefore compress the definition of a Perfect Classification into five words which students can easily memorize: "Collectively exhaustive and mutually-exclusive." That is well and good in university courses on philosophy, on the history of science, and on other CULTURAL subjects. In the TECHNOLOGICAL world of Measurement and Automatic Control, the first two requirements should be observed. Experience has shown that for instrument work these first two requirements can be replaced by the advice: "Don't waste effort on trivialities." The reason is obvious: in an occupational field with tens of millions of possible combinations, there are so many important and significant sets or groups of entities and of relations—all yielding solutions when properly classified—that a busy worker should not and need not waste his mental powers on systematizing wrapping-paper and floor-polish. Thus the first requirement amounts to selecting an important and relevant set or collection of the entities to be classified. This selection is up to each individual worker, or team of instrument men: it is a matter of good judgment, which cannot be sharpened by any words printed on this page.

To a large extent this is true also of the second requirement: that the categories be significant.

The third requirement—that the collection of categories be exhaustive—should be relatively easy to accomplish in most cases. To be sure, the actual task may turn out to be tedious and time-consuming if the list of categories must be a long one (like a Sears-Roebuck catalog), but it seldom is an intellectually difficult task.

The fourth requirement—that the categories be mutually-exclusive—may be the easiest or the most difficult to carry out. When it turns out to be an easy job, the other three requirements likewise turn out to be easy. For example the U.S. Treasury, or the Congress, established with ease a Perfect Classification of U.S. metallic and paper currency denominations to be manufactured by the Mints and the Bureau of Engraving: the cent, the nickel, the dime, etc., and the various bills: one, two, five, ten, twenty and so on to those used in Federal Reserve Bank transactions. This is an example of one of the Perfect Classifications that are easy because they are based on QUANTITATIVE GRADATIONS. Any schoolboy who knows how to count can classify a given collection of things by length, or diameter, or weight. If he is an exceptionally bright boy, he will not make the steps equal, like:

1, 2, 3, 4, 5, 6, 7, . . .

but he will devise a scheme like that of a monetary system:

0.01, 0.05, 0.1, 0.25, 0.5, 1, 2, 5, 10, 20, 50, 100, 500, 1000 . . .

or perhaps a nearly equal-percentage or logarithmic scheme, such as one of the "preferred numbers" schemes adopted by various manufacturing industries under the auspices of the National Bureau of Standards. Note that the relative *usefulness* of these various schemes is not under discussion: the point is, simply, that one type of Perfect Classification, namely the quantitative gradation, is easy to establish and that it automatically results in mutually-exclusive size-brackets—which may or may not deserve to be called true Categories.

The Mathematical Scheme

Another way of creating a Perfect Classification is based on the dictum that an instrument (or a component) is *the embodiment of a method,* and on the possibility of expressing *some* methods of measurement and of automatic control—and *most* functions of components—by equations. The practical methodology, in this case, will consist in the interlocking of the mathematical list with other lists as shown in Fig. 5, because a classification of equations, by itself, has no physical connotation: it must be related to categories of mechanisms, of chemical reactions, of electric circuits, etc. However, each single member of a category of equations may have a useful physical significance and indeed the history of mathematics is full of examples of equations originally conceived to express quantitatively some relations discovered in astronomy, in physics, in chemistry, in biology, even in finance.

The Binary Scheme ("Excluded Middle")

Still another relatively easy way of creating a Perfect Classification is to follow the doctrine that *the fewer the primary divisions the likelier the perfection.* The easiest of all, then, is a prime division into ONLY TWO mutually-exclusive categories. With luck, each of these two categories is divided into only two classes, making four mutually-exclusive classes. Then eight different types, sixteen varieties, and so on.

What does "with luck" mean? It means a combination of pure luck and of arbitrariness. It means that your MENTAL CONSTRUCTS may have to supplement your ascertainment. This can best be demonstrated by an example. Let us take, for the original collection of things, all known or possible temperature-measuring instruments. This is the tree, whose trunk is to bifurcate into two limbs, each limb into two branches, and so on. The fact that the rational or scientific classification* is different does not matter here, because this is a sort of exercise. So, for the prime division, one puts down: 1) thermometers and 2) pyrometers. Next, the thermometers are divided into: 1) mechanical and 2) electrical. These simple bifurcations may be continued as far as one likes, as shown in Fig. 6.

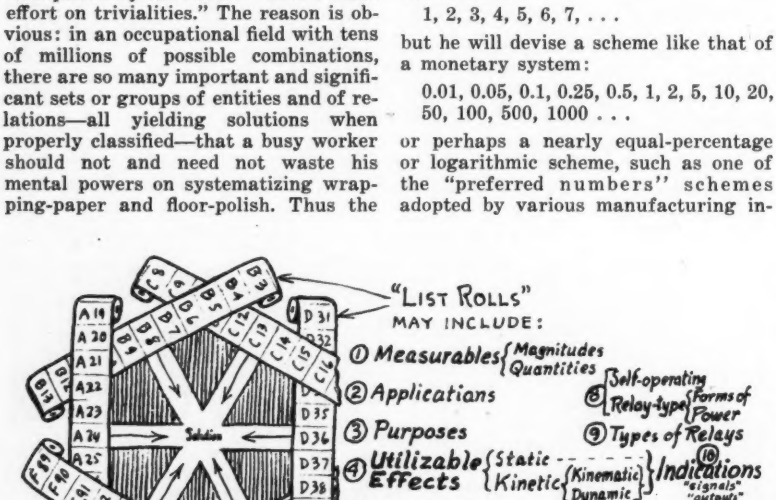

"LIST ROLLS"
MAY INCLUDE:
① Measurables {Magnitudes / Quantities
② Applications
③ Purposes
④ Utilizable Effects {Static / Kinetic {Kinematic / Dynamic
⑤ Scale Laws
⑥ Responses
⑦ Measuring Properties {Passive / Active} {Static / Kinetic
⑧ Self-operating / Relay-type {Forms of Power
⑨ Types of Relays
⑩ Indications "signals" "outputs" "inputs"
⑪ Cost, safety, &c. (non-tech. factors)
Solution
INSTRUMENT ANALYSIS and SYNTHESIS
Two-dimensional representation of "six-dimensional hypercube"

Fig. 5. This scheme (a "picture" of the six-dimensional hypercube) has never been carried out in detail with six Perfect Classifications. (Someone remarked that it would take ten men ten years.) In practice, with six brief lists, it yields an astonishingly large number of combinations. It will be found that some of these combinations had never been previously conceived.

This should not be taken too literally: it is designed to enable the reader to teach himself some important rudiments of Methodology. Consider the very first division into "thermometers" and "pyrometers": does it mean anything—can

*On page 350 of A.I.P.'s 1939 Temperature Symposium. Reinhold Pub. Co., N. Y., 1941.

it mean anything—without definitions? Of course not! But the "classes" indicate that "thermometers" have been defined (merely for the sake of this classificatory scheme) as those temperature-measuring devices which are "mechanical" or electrical"—so that, by simple exclusion, "pyrometers" have been defined as "all others"—evidently the optical and other non-mechanical non-electrical devices. But that is not all: anyone with an intimate knowledge of the field will see that the "thermometers" must have been defined as the "contact" instruments and the "pyrometers" as the "distance" instruments. Then, too, the "exhaustiveness" of the scheme depends on arbitrarily assigning to the "electrical" class most instruments utilizing non-electrical thermal effects, simply because it is possible to measure anything electrically. And the mutual exclusiveness of "expansion" and "pressure" evidently depends likewise on previous arbitrary definitions of these two effects. (The evidence is that the sub-type "solid" must include pyrometric cones, whose deformation—rather than expansion—is utilized in measurement. This means that the definition of "expansion" had been trifled with.)

The whole scheme is a fabric of arbitrary definitions. But all these unscientific definitions (plus the dozens not referred to, which would be used for filling-in all blanks) are not necessarily horrible or humorous. These definitions served one particular purpose, which was to illustrate one "Perfect" classificatory scheme consisting of a succession of simple bifurcations. The problem or exercise was to show a tree with two limbs, each limb with two branches, each branch with two twigs, and so on. Inasmuch as the tree happened to be the enormous collection of temperature-measuring instruments, and inasmuch as the true "natural history" of these instruments is not a succession of simple bifurcations, it was necessary to resort to arbitrary definitions. Note that these definitions were all implied. None appears in the illustration. And each reader can substitute his own definitions for the ones printed in the foregoing paragraph.

In like manner, each reader could start from the tree-trunk of all temperature instruments (or any other set of things or of abstract concepts) and work out a Perfect Classification consisting of a succession of simple bifurcations. You will usually find it necessary to REDEFINE categories to suit the special purpose of your classification. The reason is that this easiest of all schemes—the simple "either-or" bifurcation—probably was carried through by previous workers in the particular field which you are exploring. And even if you are the first to classify a new field, the interdependence and interlocking of all fields in Measurement and Control is such that you will run up against usages—some of them strongly rooted.

But definitions are only means to ends. They are not sacred. The only important ones are definitions of concepts, of methods, or of principles—not of things. Concepts, methods and principles are important; hence classifications are important and Perfect Classifications are the most important of all because they are the master keys which you fashion to organize your work or your ideas—to aid you in making correct decisions. The simple binary scheme of classification is the easiest, but often the ease of it comes only from your diregarding traditional terminologies.

Perhaps the oldest examples of a scientific binary classification is that of the universe into 1) atoms and 2) the Void—which, when you first read it, seemed childishly naive or sublimely profound, depending upon how carefully the author of your schoolbook explained the definitions laid down by Democritus. As a classification it is perfect, if and only if the interpreter of Democritus can answer all questions as to where to put various things; and the discussion usually brings out that "Atoms and the Void" could not have been a classification of the universe.

The great Linnaean scheme, by the way, as modified in modern times, can be said to start with two simple bifurcations:

1. Living creatures ..... { 1. Animal / 2. Vegetable

2. Dead matter ..... { 1. Organic / 2. Inorganic

It is not a classification of the entire universe but only of the Empire of Nature. As such, it still evokes the admiration of sophisticated modern scientists. But do modern scholars still consider it to be that gem of gems, a widely-useful Perfect Classification? Learned opinion has been split by modern discoveries, among them the following:

(1) Organic matter was originally defined as that created or grown only in animals or plants. It was thought "forever impossible" to synthesize not only such materials as meat, wood, etc., but even any of the chemically-simple "humors" and other liquids in animals and plants. In 1828 Wohler synthesized urea; the mutually-exclusive categories "organic and inorganic" had to be redefined;

(2) Only animals were supposed to possess the power of locomotion but today it is known that some algae and other plants move around by themselves;

(3) Many marine animals such as corals and sponges have fixed positions;

(4) Some tiny living things are neither animals nor plants, but are the constituents of animals or of plants;

(5) Bacteria are either plants or animals or both—just like radiant flux which is either waves or photons or both;

(6) Nothing could be more mineral or less living than a crystal, yet in 1946 Stanley won a Nobel prize in chemistry for turning viruses—creatures that eat and reproduce—creatures that live—into crystals, proving that these crystals were THE viruses that caused the tobacco mosaic disease, turning them back into their natural form, and repeating the "miracle" again and again.

And so on. But most modern biological scientists hold the view that questions as to algae, sponges, etc., raise themselves because the older official definitions of animals and plants were too brief; that it is a perpetual duty of international scientific bodies to revise over and over again the official definitions of the kingdoms, phyla, classes, and successive subdivisions; in short, that the Linnaean scheme was, is and will continue to be "perfect."

An extremely important point is involved. It is that the "perfection" of a classificatory scheme may depend on the degree to which the classification is public or private, universal or special. Here is one extreme: Until modern times, the great schemes of philosophy and science, though designed for world-wide acceptance and even when hailed as perfect by the scholars of "the" world (of that region and of that time), could not survive the re-examinations to which they were subjected by "new" worlds—by thinkers outside that region or later in time.

The other extreme is represented by one individual who organizes one field for one purpose. When you come up against a problem in Measurement and Control, the principal test of the "perfection" of the scheme you adopt is whether it yields the right answer. If you devise a scheme like that of Fig. 6 and if it provides YOU with a golden key, it is a Perfect Classification as far as you are concerned.

Between the two extremes there are

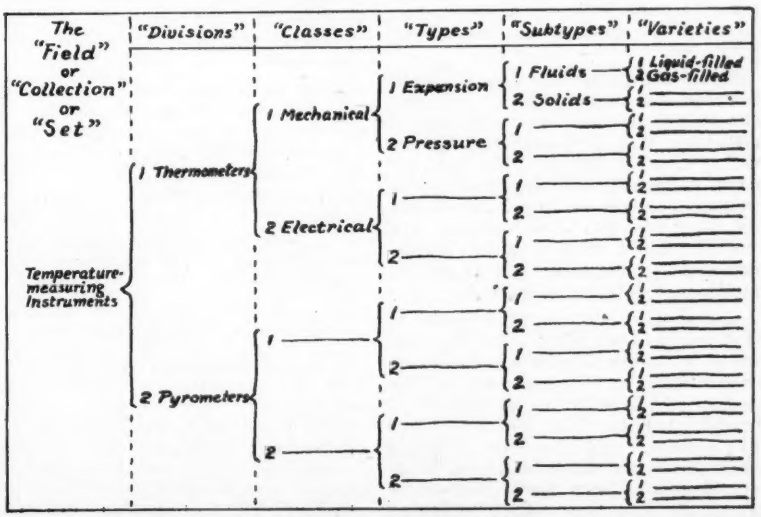


Fig. 6. In some cases, the easiest way of classifying "perfectly" is by a series of simple "either-or" bifurcations. The particular scheme shown here is unorthodox but it could be carried out in detail for a special purpose (a "non-public" purpose: see text).

innumerable examples. When you walk through a supermarket or department store, your minutes are saved by classificatory schemes which are "perfect" for that particular purpose, that is, to save you minutes. If you work in a large company, you have but to look around the room to find various printed forms representing classificatory schemes which are "perfect" for managerial and other special purposes.

Classifications of Behaviors

Linnaeus did not classify the actions of animals and plants and of their organs. He left to others the classification of "normal reactions," "conditioned reflexes," and the many other CHAINS OF EVENTS IN TIME which are the subject-matter of modern biological and psychological sciences—new sciences—and pseudo-sciences!—so numerous that *their* classification perplexes reference librarians. (No doubt that's the one reason why we all speak of "the great Linnaeus" or "the beloved Linnaeus.")

As has been stressed in preceding articles, the simplest measurement is an OPERATION; the simplest measuring system is a CAUSE-AND-EFFECT system; the simplest automatic controller is a DYNAMIC circular system in which part of the output modifies the input. About the only time you think of the tens of millions of different combinations as dead things is when you put back a portable instrument in its proper place —or when, conversely, you have to plan a stock-room for instruments and components. At all other times, your problem usually is to find the cause of an effect or to produce a desired effect from a given cause. It usually is a problem in kinematics, optics, etc., plus a problem in dynamics—although these technical words are not the ones that come to your mind. As a rule it is a problem for which there are simple solutions but which, as it presents itself, is complicated by the multiplicity of possibilities and obscured by the absence of guide-posts pointing the way to the simple (and inexpensive!) solutions.

Hence the immense value of classifications—or even lists—of utilizable effects, of methods, of functions, of responses, that is to say of categories rather than of things. This does not mean forgetting the classifications of things; it means bearing in mind that *an instrument is the embodiment of a method.* And a method implies cause-and-effect sequences in time as well as positional relations in space.

Hence, also, the immense value of that methodology which employs cross-reference or interlocking classifications, as sketched in Figs. 4 and 5. The greater the number of classifications brought together, the less they need be "perfect," and the more certainly they jointly put up guide-posts. Without such guide-posts, the worker wastes so much time and effort exploring blind alleys that he may give up in despair.

Michael Faraday, in England, and Joseph Henry, in America, both experimented with permanent magnets and with continuous-current electromagnets for about ten years until, perhaps on the same day and probably within the same week of 1831, each plunged a bar magnet quickly into a coil connected to a galvanometer and saw the needle jump, then saw the needle jump again as he quickly withdrew the bar magnet from the coil. Hundreds of workers had been experimenting with permanent magnets, electromagnets and coils since Oersted, Ampère and Wollaston had made their disclosures in 1820-1821, and it had never occurred to any of them before 1831—not even to Faraday and to Henry—that the way magnetism produces current is by CHANGE: either a POSITION change (motion of magnet and coil in respect to each other) or an INTENSITY change without mechanical motion (starting, stopping or varying the primary-coil current). Either mode of change, of course, is a TIME change.

Numerous possible *combinations* of permanent magnets, coils, batteries, galvanometers, etc., were all being tried out by hundreds of the world's keenest minds. Early in 1831, if a modern type opinion poll had been taken among these workers, the result would have been: "(1) All of us agree that since an electric current produces a magnet, the converse should be true; (2) every possible combination has been tried in vain; (3) therefore our conclusion is that if a magnet can produce a current, it will have to be by means of new apparatus yet to be invented. (4) However, being scientists and not charlatans, we humbly admit the possibility of magnets producing currents by means of our familiar apparatus in one of its well-known combinations PLUS some environmental factor or experimental condition which none of us can imagine. (5) P.S. Certain acquaintances of ours suggest that there is a simple answer which escapes our minds because, although in general we make good use of our minds, we do not use our minds METHODICALLY in this particular search."

(The sermonette that naturally follows this specially-slanted narration of the discovery of electromagnetic induction is so obvious to you that you can write it and paste it over this parenthetic paragraph: Whatever form your preachment may take, it will no doubt serve your own purposes better than one addressed to tens of thousands of readers.)

Using Published Classifications

Fig. 5 names only ten types of lists, all pertaining to Measurement and Control. This should not be considered as implying that you should not choose any "fields" or "sets" or "collections" which are not intimately associated with Instrumentation. On the contrary! If, for example, you come up against a problem involving a choice of metals, you would do well to include among your classifications one or more of the conveniently arranged tables to be found in the ASM's "Metals Handbook" or other such reference work. The same applies to all materials: a tremendous amount of work has been done in thousands of research laboratories to ascertain the physical and chemical properties of the elements, of nearly a million different compounds, mixtures, alloys, etc., and of thousands of different commercially-available materials; also the variations of these properties with temperature, pressure, electric fields, magnetic fields, radiations, and other conditions. This information is available. Most of it is conveniently arranged; the chemical data, especially, are admirably arranged in frequently-revised books and the newest tables are quickly published in periodicals. Some excellent sources pack into a few pages hundreds of leads to fields that have been thoroughly classified.

Although this aims to convey an attitude rather than to encourage routines that stifle imagination, the availability of so many valuable published classifications compels advising that they should not be neglected when using the procedures of Figs. 4 and 5. You should use these tables in conjunction with your own, rapidly going through some kinds of possible combinations that are obviously far-fetched, but s-l-o-w-l-y exploring the possible combinations that are startlingly new and hence "virgin territory" unexplored by the other workers in your specialty. Bear in mind that when it comes to materials, the exploration of *all* possible combinations for all instrumentation purposes would cost more than the total volume of instrument sales; the instrument companies can't do it. Year after year, however, some of the greatest innovations are made possible by "new" materials—new only in the sense of previously untried—and in most cases the ideas of instrument users faced with special problems. In many such cases, the material had been considered and rejected because of one well-known factor which was such an obvious disadvantage that further consideration—and time and effort—would have been against "common sense." In many such cases, too, the story parallels almost exactly the following one (chosen because it is *not* an instrument-innovation story):

The traction companies seemed to delight in cramming the little cars with passengers and then expecting them to grind up steep hills. Their motormen refused to turn the power on gently; service mechanics did not bother . . . Motors were forced to run without overhaul . . . The factory was clogged with machines returned for repair. The Jonah of the situation was the hard copper brush . . . They all realized that a radical departure must be made in brush design or else the traction job must be given back to the horse . . . One day Van Depoele said rather hopelessly to Rice, "Why don't you try a brush made of carbon instead of copper?" Rice turned to him in astonishment. The idea was obviously absurd . . . The Professor was doubtful, too. Common sense had ruled out carbon for brushes long ago. But he agreed that the idea was no more absurd than some other impossibilities that had worked . . . Professor Thomson stood

looking at the world's first sparkless commutator a moment and then said, "Van Depoele, that is the solution we have been looking for. You have showed us something that has been right in front of our eyes for years." That same day he had a set of carbon brushes made up and sent Rohrer to Woonsocket to install them on a car. Whereupon the ailing little trolley ran for 4,000 miles without brush trouble . . . It was no miracle, but the simplest kind of logic. Carbon, being glass smooth, did not wear the commutators but polished them. Its resistance, as Rice had said, was a thousand times too high. But it was only necessary to give the new brush a thousand times the area of contact in order to drop its resistance to that of the finest copper. Until Van Depoele suggested it, every engineer in the world had ignored that simple bit of reasoning. [From "Beloved Scientist" (Elihu Thomson) by D. O. Woodbury, pages 191-193.]

(Again you can substitute, for this parenthetical paragraph, your own sermonette on classifying not only all the properties of the materials under consideration, but also the MUTUAL properties of pairs of materials.)

The Nature of the Field or Set

It is well to repeat that making perfect classifications is sometimes easy and sometimes difficult. In Measurement and Control there are fields or collections that present difficulties because of their nature. None of these will be named here because its selection might defeat the intended purpose. Instead, there is selected a collection which, at the time of writing, numbers 2.5 billion separate entities and which has never been classified into mutually-exclusive categories for the simple reason that although no two members are alike and although the differences between extremes are obvious, there are no visible dividing lines but only imperceptible gradations. When Linnaeus tried to subdivide the species Man, he noticed and announced that there were no subspecies and he merely recognized the existence of geographic groups most of whose members (but never all) had in common a color of skin, a texture of hair, etc. Race hatreds had existed since prehistoric times and had been inflamed by leaders bent on conquest; but it was less than a hundred years ago that a European nobleman wrote the first book attempting to prove the inferiority of all races except the one to which he claimed to belong. This book sold profitably for several decades. Many other authors likewise went after the easy money of suckers who enjoy seeing their prejudices in print, but the fact remains that, as George A. Dorsey puts it, "Races do not exist; classifications of mankind do." What is especially pertinent here—what makes the human species an excellent example of a collection difficult to classify "perfectly"—is the TOTAL ABSENCE OF CORRELATIONS: Every attempt to discover correspondences between appearance factors such as color, and other factors such as those of lungs, digestive system, blood, cardiovascular system, nervous system, brain size, muscular strength, intelligence, etc., has failed utterly. No mutually-exclusive categories could be detected until recently when blood-types were discovered: These, the first sharply-defined divisions of the human species, cut across all other divisions! Hence the persisting fascination of the subject and the stream of books on "races"—from the emotional twaddle of Gobineau, Wiggam, Grant, Osborn and Stoddard to the factual scholarship of Carlson, Morgan, Boas, Haddon, Dorsey and Hankins. Hence the benefit derived by students of Methodology when they compare the former with the latter, Hence the encouragement you can derive—when facing a tough classificatory problem—from knowing that it is easy in comparison with the classifications of mankind.

Conclusion

"The proof of the pudding . . . " To the initial assertion that this article "may" provide a key to greater success in instrument work, there must be added in conclusion the report that some prominent Instrument Men attribute part of their success to the early teachings on the methodological approach to Instrumentation—in spite of the fact that these early lectures and writings lacked the polish of this article. (But this cold-print article lacks the transmissible fervor of words spoken from meeting-room platforms.) There must be added also the specific assurance that time spent in classifying things or concepts pertaining to your work cannot and will not be wasted time—must and will be well-spent time—especially if you do not expect Methodology to pull rabbits out of hats the moment you start applying it. As Emerson said: "Skill to do comes of doing."

Examples in the Literature.—It is obviously impracticable to print a sort of roll of honor of outstanding classification-type solutions of instrument problems—and it would be presumptuous to do so. However, in recent years an increasing proportion of the technical papers reporting brilliant solutions of measurement or automatic-control problems bear evidence that their authors did use classificatory methodology. In addition, a number of engineers and engineering professors have published books and papers, and have inaugurated courses, in which they feature classifications based on homologies, inductive-and-deductive logic, etc. Following are a few examples, representing about one-tenth of all the writings that could be cited—selected for three reasons: (1) the present author is personally acquainted with their authors; (2) each article or book features a classificatory scheme DIFFERENT from those originated by the present author; (3) each of these schemes, whether "perfect" or not, is well worth careful study by Instrument Men:

1934

LEV A. TROFIMOV, "Filing Technical Ideas," *Instruments*, Vol. 7, June 1934, pages 106-107. Advice on solving technical problems, based on Prime Division into: 1) class of problems, 2) kind of force, 3) states of substance, 4) prevailing conditions, 5) associative elements; with 19 secondary divisions. This was Trofimov's brief first disclosure; see also his later writings in other technical journals; also his course on the "Theory and Technique of Inventive Practice."

1939

C. S. DRAPER and G. V. SCHLIESTETT, "General Principles of Instrument Analysis," *Instruments*, Vol. 12, May 1939, pages 137-142. The first detailed mathematical classification of responses of "elementary instruments" (the pressure gage and the thermometer) to: 1) sudden, 2) gradual and 3) sinoidal changes in the measured magnitude. Three half-page tables of equations and twenty graphs. Absence of square-wave, pulse, "statistical," and other inputs analyzed by later workers does not lessen the importance of this article as a milestone.

1942

HERBERT ZIEBOLZ, "Characteristics of Hydraulic and Pneumatic Relays as Energy-converting Devices," *Instruments*, Vol. 15, September 1942, pages 340-345. Based on Prime Division into 1) force, 2) pressure, 3) space; hence 27 possible categories of conversions: a) nine proportional, b) nine square-root, c) nine second-power. See also same author's "Analysis and Design of Translator Chains" published Sept. 1946 by Askania Regulator Co.: Prime Division here consists of a list of 19 measurables, hence 19^3 possible combinations. See also Ziebolz perpetual card index service using his classification.

1944

ED SINCLAIR SMITH. Table I (pages 104-105) with text on pages 96-115 and Table III (pages 117) with text on pages 115-119, of "Automatic Control Engineering" (McGraw-Hill Book Co., N. Y., 1944). Table I classifies hundreds of mathematical expressions of physical components into 32 "cases." Table III, with seven rows of conditions and seven columns of coefficients, gives 49 "answers" in terms of stability, steady hunting, etc. Both are triumphs of the methodological approach.

1946

I. F. KINNARD. "Functional Analysis of Measurements," *"Transactions A.I.E.E.*, Vol. 65, 1946, pages 987-994. Prime Division is into: 1) primary "detector," 2) intermediate "means," 3) "end device," and there is an independent alphabetical list of eighteen "basic elements" (capacitors, coils, contacts, eddy-current disks, electric sources, etc.), enabling cross-classifications. Another table (Fig. 11) gives "Frequency of occurrence of basic elements."

* * *

In conclusion, a few leads to references to general classifications for readers interested in the general subject:

(1) Organic chemistry classifications and nomenclature as described and discussed in numerous periodicals: Ask a technical librarian to select references analyzing (a) the tremendously complicated basic problems, (b) the new problems created by the silicones and other new categories of compounds paralleling the carbon compounds. This reading will be exceedingly profitable to non-chemists.

(2) Natural history: Ask your librarian to select references on the modern *revisions* of the Linnaean definitions—probably indexed under "Taxology" and "Taxonomy."

(3) Critical discussions of the definitions of "set," "class," "collection," "number," etc.: An easy-to-read start is Chapter 29 of "Men of Mathematics" by Eric Temple Bell: read pages 571-574 and you will know whether this subject bores you or fascinates you. If it bores you, don't go on; if it fascinates you, take out the book and ask the librarian for similar chapters in other non-technical ("cultural") books on mathematics, then on mathematical logic.

(4) Classificatory systems used by U. S. and foreign Patent Offices; also the numerical and other schemes used by abstract services, libraries, etc.: From a broad general viewpoint, most of these are disappointing. All of them, of course, are interesting as specific solutions of special problems. All of them, moreover, display the praiseworthy desire of their founders to save the time of their users.

(5) "The Anatomy of Melancholy" by Robert Burton (1577-1640). Incomparable as a masterpiece of classifying and correlating immaterial entities. You needn't borrow a copy from a library and read it from cover to cover: take it from the shelf, thumb through the first thirty pages and you will discover what is applicable to your self-training in Methodology.

(6) Classification of "everything" by ancient, medieval and modern philosophers. Consult (a) your minister, priest or rabbi, (b) an ultra-modern professor of philosophy, (c) a librarian. Don't miss two tabular classifications: the one by Hobbes as printed on pages 376-377 of Vol. 34 of the first edition of "The Harvard Classics" and the one by Ouspensky at the back of "Tertium Organum"; both will make you smile, then reflect.

The Direct-reading D-c. Strain-gage Bridge

By ROBERT W. TROKE, Flight Test Engineer, North American Aviation, Los Angeles, Calif.

Editor's Note: The material in this article is of special interest to aircraft research laboratories. The second part of this article will appear in our May issue.

Introduction

BONDED resistance-wire strain gages are being used more and more for studies and improvement in safety and performance of aircraft. They are also being used in many other fields for the measurement of stress and strain as well as other physical forces and dimensions.[1] A table of strain-gage applications is given here.

TABLE OF STRAIN-GAGE APPLICATIONS

I—Measurement of Stress and Strain

1. Measurement of strains in loaded parts, structures, and machines where no accurate method of mathematical stress analysis is available.
2. Experimental stress analysis for the purpose of developing new methods of mathematical analysis and for the purpose of refining present methods which often are inadequate.

II—Measurement of Forces

1. Measurement of loads in pounds and moment loads in inch-pounds.
2. Measurement of linear and angular deflections.
3. Measurement of hydraulic and gas pressure in pounds per square inch, inches of mercury, or inches of water.
4. Measurement of miscellaneous forces and conditions such as acceleration, velocity, rotational speed, horsepower, temperature, displacement, frequency, etc.

For a considerable time it has been realized that the main difficulties encountered in the use of these strain gages have been in the instrumentation used and not in the strain-gage elements themselves. The use of the direct-reading d-c. strain-gage bridge for dynamic testing eliminates difficulties experienced from using amplifiers for amplifying the output from each strain-gage channel. Systems using amplifiers often use an a-c. carrier for the bridge voltage, necessitating balancing for reactance as well as for resistance in each channel. Cumbersome and awkward instrumentation is a major cause of erroneous and unreliable strain-gage data as well as the main cause of maintenance and operational headaches.

The main advantage of the direct-reading d-c. strain-gage bridge lies in its simplicity. The output of the strain-gage bridge is fed directly to an instrument. This instrument may be the galvanometer of a recording oscillograph or some other recording or indicating device. Recording oscillographs are popularly used for this purpose because galvanometers have been developed with high sensitivity and suitable frequency response. It is customary to use a strain-gage bridge feeding a galvanometer directly to measure strains to 10^{-5} inches per inch with a frequency reponse limit over 100 cycles per second. Strains of higher frequency may be measured with galvanometers having higher frequency response but less sensitivity. The direct-reading d-c. strain-gage bridge is well adapted to flight testing and similar testing where the strains and forces usually measured are of relatively low frequency, i.e., less than 150 cycles per second.

This discussion will be divided into the following three parts: Types of Bridges, Calibration of Bridges, and Practical Considerations. The equations and procedures presented here are especially adapted to the direct-reading d-c. strain-gage bridge, but may be used with any resistance-wire strain-gage instrumentation known to the author.

(1) According to engineering nomenclature, stress is an internal force developed by the material to resist an applied load; strain is the change in dimension caused by a load or force. It is the change in dimension, or strain, that is measured by the resistance-wire strain gage; from this strain value, the stress can be computed.

Legend

R	Resistance of one bridge arm.	E	Modulus of Elasticity.
R_{sh}	Resistance of calibration resistor.	G	Modulus of rigidity.
		u	Poisson's Ratio.
R_m	Instrument resistance.	Δ	Change in.
N	Number of active arms.	C	Gage factor.
N_E	Effective value of N.	b	Ratio of transverse sensitivity to axial sensitivity of a strain gage.
f	Unit stress.		
psi.	Pounds per square inch.	L	Length.
e	Unit strain.	V	Bridge supply voltage.
e_x	Strain on x-axis or actual strain.	v	Bridge output voltage.
		i	Bridge output current.
e_t	Total strain indicated.		

Types of Bridges

Each strain-gage channel consists of a separate bridge of the Wheatstone type as shown in Fig. 1. This bridge consists of four arms, designated as A, B, C, and D. Each arm consists of one or more strain gages, the total resistance of each arm being kept constant. Those arms which are bonded to the test specimen are called active arms. The inactive arms are bonded to a similar material (aluminum, steel, etc.) having the same temperature as the test specimen but not subject to stress. When all four arms of the bridge are active, all are bonded to the test specimen and it is not necessary to make specific provisions for mounting inactive gages.

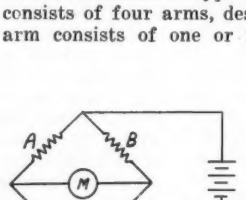


Fig. 1

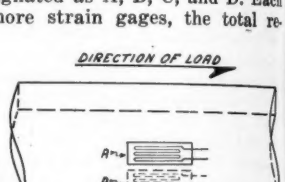


Fig. 2

It is obvious that the ideal and best temperature compensation exists when all four arms of the bridge are active. Temperature compensation is extremely important since very small temperature changes will produce spurious strain readings unless they affect all bridge elements alike. Using four active gages has the added advantage of increasing the output of the bridge, thus increasing the sensitivity and reading accuracy.

An outline of the most common and usable strain-gage bridges is presented here. A sketch is included with each bridge type discussed. The designation applied to each bridge is fairly simple. A designates a bridge used to measure axial strains; B, bending; and S, shear. Different bridges may be used to measure each of these strains. The number appearing after the letter is used to designate the particular bridge chosen and described.

Axial Strain Measurement

A1 Bridge: This bridge has two active arms and two inactive arms, N = 2. Arms A and D are active and are mounted on the test specimen. Arms B and C are inactive and are attached to unstressed material of the same type as the test specimen. If the test material is aluminum, for example, the dummy gages are mounted on a small aluminum plate which is mounted near the active gages in such a way that the plate will not be stressed at any time. It is most common to use only one strain gage for each of the bridge

arms. The active gages, A and D, are mounted back to back on opposite sides of the test specimen whenever possible; thus only axial strain is measured and bending strain is canceled. Fig. 2 illustrates the mounting of the active gages A and D, for this bridge.

A2 Bridge: All four gages forming arms of this bridge are active, N = 4. This bridge may be used when it is desired to measure an axial strain in a uni-axial stress field. Gages A and D are mounted with their axes parallel to the direction of the stress. Gages B and C are mounted with their axes normal to the axes of gages A and D. Each pair of gages should be mounted back to back whenever possible.

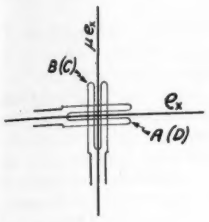


Fig. 3

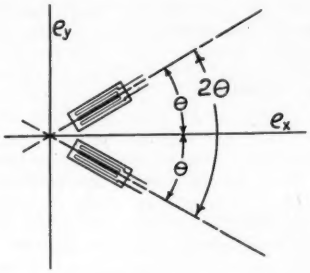


Fig. 4

Two "X" type gages may be used for this bridge. An "X" type gage consists of two gages mounted perpendicular to each other with their axes forming an "X" or cross. Fig. 3 shows how an "X" type gage is mounted in a uni-axial stress field to measure the axial strain. The bridge arms given in parentheses, D and C, are mounted directly opposite each other on the other side of the specimen under test. The same results are obtained by using four single-type gages with the two gages on each side mounted perpendicular and adjacent to each other. The A2 bridge has the best temperature compensation and the greatest sensitivity of the axial bridges. The increased output is produced by what is known as Poisson's ratio. When a bar is compressed, its cross-sectional area is increased: when it is elongated by a tension load, its cross-sectional area is reduced. Poisson's ratio is the ratio of unit lateral contraction to unit axial elongation. The value of Poisson's ratio u varies for different metals, but is roughly about 0.3 for most metals in the elastic range.

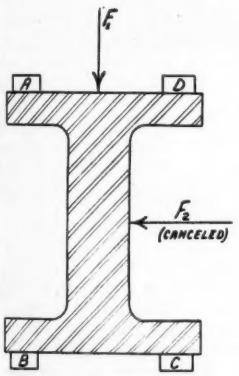


Fig. 5. B1 Bending Bridge

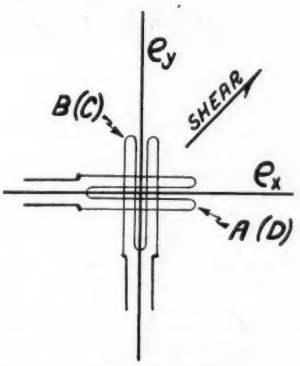


Fig. 6. S1 Shear Bridge

A3 Bridge: This bridge has two active and two inactive arms, N = 2. This configuration of gages is sometimes known as the dyadic or stress gage and is used to determine an axial stress in a bi-axial stress field. The active arms are mounted as shown in Fig. 4. It is sometimes preferable to use two gages for each of the active arms, A and D, and mount them back to back in order to cancel bending effects. The gages of each arm may be wired either in series or in parallel. Arms B and C are inactive and are attached to unstressed material of the same type as the test specimen. The angle θ is so chosen that the ratio of sensitivity to strain in the Y-direction to sensitivity to strain in the X-direction is equal to Poisson's ratio for the material being tested. Hence, strain in the Y-direction is canceled and only strain in the X-direction is measured. The magnitude of θ depends upon Poisson's ratio u for the material being tested and upon the transverse sensitivity of the strain gages used.

Nearly all bonded resistance-wire gages have some transverse sensitivity because of their construction. In most gages it is necessary to use a network of parallel wires necessitating loops at the ends. These loops are sensitive to transverse strains. Looking at Fig. 4 again, we see that the grid of each of the strain gages has five loops, each of which is sensitive to strains transverse to the axis of the gage. The ratio of transverse sensitivity to axial sensitivity for a strain gage is here designated as b. The most common values of b are found to be 0.01 to 0.04. The transverse sensitivity of a strain gage may be determined by mounting samples of the gage in axial and transverse directions on a tensile bar and making a calibration test. A rough approximation of the value of b may be made from an examination of the construction of the strain gage; the value is found by dividing one-half the width of the active part of the gage by the total length of wire in the strain gage parallel to its axis. Satisfactory values of b for different gages may be obtained by writing the manufacturer.[2] Some of the gages and their ratio of transverse sensitivity to axial sensitivity are as follows: SR-4 type A-1, b = 0.02; type A-3, b = 0.02; type A-5, b = 0.035; and type A-12, b = 0.01.

The value of the angle θ for this bridge is determined from the equation:

$$\tan^2 \theta = \frac{u - b}{1 - ub} \qquad (1)$$

When the value of b is very small and is neglected, this equation becomes $\tan^2 \theta = u$. From this equation we find the value of 2θ for an A3 bridge mounted on aluminum to be about 60 degrees; on steel, about 57 degrees.

Bending Strain Measurement

B1 Bridge: This bridge has four active arms, N = 4. Gages A and B are mounted back to back; so are gages C and D. Axial strains are canceled and only bending strains are measured. Gages A and D and gages B and C are usually mounted either side-by-side or end-to-end. When it is desired to cancel a secondary bending strain as well as axial strains, the gages can often be mounted to accomplish this. An example of this appears in Fig. 5. This figure shows the cross-section of a beam with a strain-gage bridge mounted to measure bending due to force F_1 and cancel bending due to force F_2. Many other applications of this principle are possible.

Shear Strain Measurement

S1 Bridge: This bridge has four active legs, N = 4. Two pairs of gages are mounted perpendicular to each other. Gages A and D, as well as gages B and C, are mounted back to back. In this way bending and buckling effects are canceled and the shear strain is measured at 45 deg. to either axis. "X" type gages are generally used for this bridge. Fig. 6 shows an "X" type gage mounted to measure shearing strain in a bi-axial stress field of mutually perpendicular stresses. The bridge arms given in parentheses, D and C, are the elements of another "X" type gage mounted directly opposite on the other side of the specimen.

Discussion

Sometimes it is desired to determine a shear stress when the directions of the principal stresses are not known. There are several accepted methods of doing this. One method is to use three bridges of type A1 with the active gages mounted in an equilateral triangle; sometimes called a delta rosette. The axes of the active part of the gages are 60 deg. apart. Considerable material has been written about this delta configuration as well as others; all methods seem to require a comparatively complicated reduction pro-

Continued on page 450

(2) The Baldwin Southwark Division of the Baldwin Locomotive Works has purchased the patent rights of the bonded-wire resistance gage and manufactures them under the trade name SR-4.

Remote Supervision *of* Industrial Production Processes

By F. C. EVANS and W. G. HOLZBOCK, ADT Company, New York

IS IT possible to operate a factory without human attendance? Each technical advance brings us closer to the realization of this idea. Milestones on this road are instruments which measure and control. There is hardly an operation in modern industrial production which cannot be mechanized and controlled automatically.

The logical consequence might seem to be that the fully automatic factory is just around the corner. However, we still have quite a number of human attendants in most industrial processes and we will, for some time, continue to have them although on a constantly reduced scale.

Reason for Continued Human Supervision

The reason is twofold. First, the best automatic control device is subject to failure. Even if it were capable of running for 50 years, the 51st year might see its undoing. Second, if instruments are to replace manpower, their use must be more economical for the employer. The cost of complex instrumentation that would be required to convert some operations into automatic processes might constitute a major investment. For this reason, where production programs are subject to frequent changes, the use of manpower is often preferable from an economic standpoint.

Where automatic mechanization is employed, the operations invariably involve a degree of supervision, either by persons on the premises or through devices which register at a remote point when irregularities occur. This remote supervision is supplied in many areas by an outside central station where operators are constantly on duty to secure suitable corrective action upon receipt of signals indicating an abnormal condition.

Fig. 1 shows a typical central station in which constant supervision is maintained over many different conditions in the premises of hundreds of subscribers.

Take the simple function of an oil burner. Control equipment for this purpose has been practically perfected and when, for example, the oil flame in the furnace goes out for some accidental reason, the oil burner immediately shuts down to prevent un-ignited oil being sprayed into the hot combustion chamber. This, of course, means loss of heat and a quick restoration is desired. Here, the central station steps in and calls the human attendant who can then look after the causes of the shutdown and restore operating conditions.

The ideal central station would supervise the following:

1. Dangerous or abnormal conditions which the automatic controller cannot detect or react to.
2. Any shutdown of the automatic process controller.
3. Any abnormality or breakdown in the automatic controller, itself.

Central Station Supervision

Let us trace the evolution of this type of supervision. The night watchman and the manual fire alarm in factories are ceding their places more and more to automatic burglar alarms and automatic fire detectors. No attendant personnel is required because the plant is supervised by an outside central station which concentrates in one office the supervision of hundreds of small and large industries, institutions and mercantile establishments. Whenever a burglar enters a protected area or a fire breaks out, a distinctive signal is automatically transmitted to the central station and appropriate action is taken immediately.

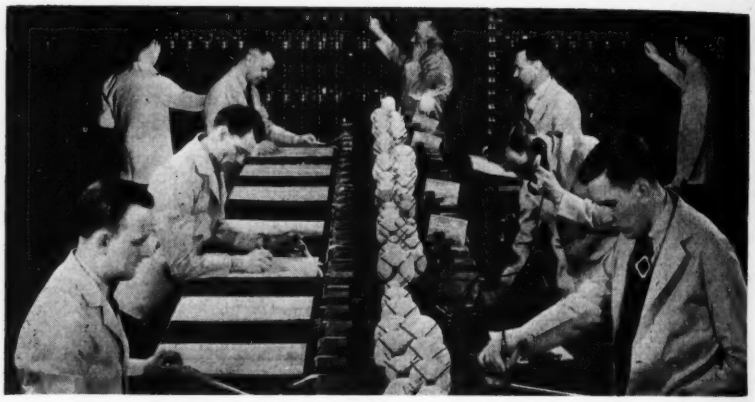


Fig.1

The same principle is being applied to industrial processes which are supervised from the same central station through devices which initiate a signal whenever one of the three previously mentioned conditions arises.

The automatic controller thus becomes perfectly geared with the human element. Many industries which heretofore have preferred human supervision because of unanticipated conditions which might at times offset the action of the controller, have become receptive to the use of automatic controls because of the supervision supplied by a central station.

When remote supervision began to extend beyond the field of burglar and fire alarms the new applications were considered to be auxiliaries. Automatic burglar and fire alarms, in many cases, permitted the management to dispense with watchmen entirely, usually without affecting insurance rates and often making substantial payroll savings, which have multiplied in importance under present-day high-wage and short-week conditions.

In many cases the watchman took care of the heating system, making sure that the employees arriving in the morning found their working quarters at an appropriate temperature, or that process steam was available. The same watchman might also keep an eye on vats or ovens to maintain the required temperature. If this watchman was to be replaced by automatic burglar and fire alarm—who would take care of these smaller and yet vital details?

Parallel Controls

These were the problems that led to the paralleling of controls for a heating system with a second set of controls used merely as initiating devices for transmitting signals to the central station. For example, if the heating system is fired by an automatic coal stoker, there is always the possibility that the coal feeding mechanism will become jammed by a foreign object such as a railroad spike.

The manufacturers of stoker equipment recognize this and to overcome it they provide a shear pin or equivalent which disconnects the coal feeding mechanism from the driving motor when a jam occurs. This does not prevent the coal in the fire box from burning down to the grates, perhaps burning them out. It acts, however, to cut off the heat from the building. The lack of heat might interrupt production, particularly if it should result in a freeze-up of important pipes or render the premises temporarily uncomfortable for a part of the next working day.

The remedy for this is a device con-

nected to the shear pin so that a signal will be transmitted to the central station if the shear pin breaks. Should that happen, the central station will promptly notify the proper persons who will take corrective action.

When gas is used for heating, the burners are usually equipped with pilot flames to ignite the gas mixture when it is turned on. To supervise the gas burner, a thermocouple is installed directly in the pilot flame. The heat develops a current in the thermocouple

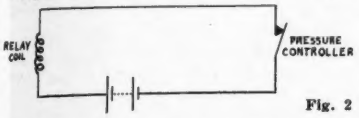


Fig. 2

which holds a relay energized. If the pilot flame fails, its heat fails and the relay drops off, thereby initiating the sending of a supervisory signal to the central station.

In any heating system it is dangerous to have the water level in the boiler too low. To detect this condition a low water alarm switch is installed independent of any controls which the boiler may have of its own. This alarm switch is connected to the central station by means of a code-sending supervisory transmitter.

Likewise, it is a simple matter to supervise the boiler against unduly high or low steam pressures. Such supervision detects and reports dangerous conditions upon a rising pressure, and helps to anticipate loss of heat in the building.

As an additional safeguard a low-temperature thermostat usually is installed at the most vulnerable place in the building, so that if the temperature starts to drop towards freezing, the central station gets a signal in ample time for corrective action to be started. In many industrial establishments there are processes wihch call for the maintenance of temperatures at pre-set high or low levels 24 hours a day, 7 days a week. Sometimes failure

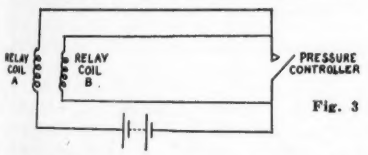


Fig. 3

to maintain the proper temperature can cause a serious loss of production.

For example, the temperature of molten zinc in zinc galvanizing vats is often supervised in order to assure that the zinc stays liquid under the influence of an automatic heating system. A galvanizing plant would certainly be at a loss if the zinc bath froze up over the week-end since the following Monday no work could be done because it takes six to eight hours to get the vats back to proper temperature.

An interesting counterpart to this, is the temperature supervision of chutes which handle the hulls and chaff from coffee grinders. Such chutes often work at normal temperatures somewhere around 300 F. This is dangerously close to the ignition temperatures of the coffee hulls, which are in the range of 400 to 500 F.

In still other places it is important to see to it that temperatures do not vary more than half a degree or so one way or the other. Some biological materials must be stored at exact and critical temperatures. Supervision of the temperature of deep freezers in food stores, etc., is also important.

In many plants it is necessary to assure the continuity of operation of machinery. In the paint manufacturing business, for example, the pigment grinders and the paint mixers are left operating throughout the night while the plant is closed, but if the machinery should stop, large batches of paints and pigments might be spoiled.

To guard against this, the rotating shafting of such machinery can be

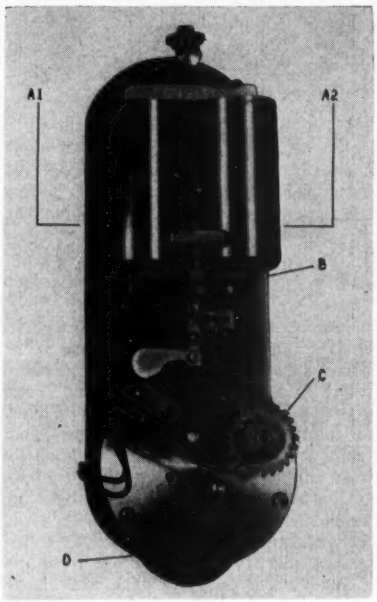


Fig. 4

equipped so that a small switch will oscillate back and forth between two contacts. If the switch keeps on going it maintains a constant cycle of charging a condenser, discharging the condenser into the coil of a relay, and charging the condenser again; but if the machine should stop rotating the condenser charge will not be renewed, and this causes a machinery stoppage signal to be automatically transmitted to the central station.

It is not surprising that these supervisory methods which started out to take over the watchmen's chores should conquer more and more fields and have become the guardians of many industrial processes.

Remote supervision of industrial processes by means of central station service is already well accepted by industry, and its use is increasing daily. The methods by which it is accomplished are described in the following.

The supervision of pressure in a closed vessel is taken as basic example: viz. When the pressure rises above a predetermined maximum a signal is to be received in the central station.

The most important constituents of this system would be:

(1) The detecting means (i.e. the pressure switch);
(2) The supervisory circuit;
(3) The transmitter;
(4) The transmitter circuit;
(5) The central station (or receiver).

The pressure switch as a detecting means needs no further description.

The supervisory circuit connects the pressure switch to a power supply and to the relay which is part of the transmitter. Fig. 2 shows the schematic wiring. Under normal conditions the circuit is closed and the relay is energized. When the pressure switch opens because of an undue rise in pressure, the relay de-energizes and this will allow the prewound spring-driven transmitter to transmit a signal to the receiver at the central station. Such a signal consists of a sequence of dashes which constitute a distinctive code, as will be subsequently explained.

In case the supervisory circuit is broken at any point, the relay also de-energizes and the same signal is transmitted as for unduly high pressure. This calls the attention to an abnormal condition although it does not distinguish the origin of the trouble. Where a clear-cut distinction of both trouble conditions, open circuit or high pressure, is advisable, especially where circuit trouble is likely at times (long runs of wire, unfavorable atmosphere, etc.), a modification is possible, the principle of which is shown in Fig. 3.

Instead of one relay, as in Fig. 2, two relays are now used and the transmitter can be made to transmit two differently coded signals. One signal would be transmitted when relay B in Fig. 3 de-energizes, while relay A picks up (i.e. energizes). A different signal would be transmitted when both relays become de-energized. The first condition occurs when the pressure rises to or above the supervised level; the second, in case of a break in the connecting lines.

In this circuit, the pressure switch, as shown in Fig. 3, is normally open. Relay B is of a high-resistance winding and being connected in series with relay A, the latter will not be sufficiently energized to pick up because of the high voltage drop in relay B. However, relay B is fully energized under this condition. When the pressure switch closes, in response to an unduly high pressure, relay B becomes shunted and de-energizes while the increase of current energizes relay A, causing a signal to be transmitted.

In case of a break in the connecting line, B would de-energize, and A would not energize. This would also originate a signal although modified from the former case by the simultaneous lack of energy in both relay coils. A clear distinction between the indication of unduly high pressure and a break in the wiring is therefore accomplished.

Actual circuits are sometimes much

more complicated but are usually based on the same fundamental principles described above.

A typical transmitter is shown in Fig. 4. When the transmitter coil consisting of windings A1 and A2 de-energizes, the armature B drops, thereby releasing a pre-wound spring-driven clock mechanism which starts to rotate the code signal wheel C through, say, two complete revolutions, after which the clock mechanism will stop and remain so as long as the relay coil is de-energized. Once the transmitter coil becomes energized again, it again unlocks the clock mechanism allowing it this time to rotate the signal wheel through, say, one revolution and relock it there as in the initial position.

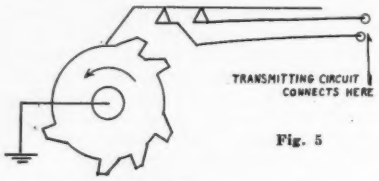


Fig. 5

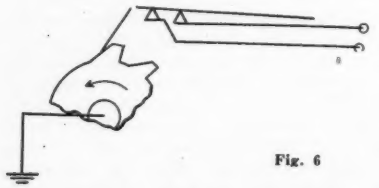


Fig. 6

This, besides limiting the duration of the signal allows the distinction between the two-round TROUBLE signal and the one-round RESTORATION signal which would originate when normal conditions become restored.

As the code signal wheel C turns, its teeth contact the contact spring pile-up D; and a switching sequence takes place which becomes quite important and must be explained in detail.

Fig. 5 shows a signal wheel and its contact springs. Note that the signal springs themselves are composed of three leaves, two being shorter than the third. The upper spring is bent in such a way that it is raised by each tooth of the rotating signal wheel. This spring has no wires connected to it. The two lower springs are both normally in contact with the upper spring, and one circuit wire is connected to each of these springs. These are the "in" and "out" wires of the transmitting circuit.

Referring to Fig. 6 it will be seen that, as the signal wheel rotates and the first tooth touches the end of the upper spring, all springs of the assembly become grounded through the signal wheel.

In Fig. 7 it may be seen that, when the tooth of the signal wheel has passed still farther and the upper spring continues to rise, the lower springs do not follow and as the shunting upper spring becomes detached from the lower ones, a break in the transmitting circuit is produced.

Finally, in Fig. 8, the tooth has passed out from under the spring and everything is ready to repeat the sequence when the next tooth touches the springs, i.e. ground, break, normal.

The transmitter is connected to the receiver at the central station and each break in the transmitting circuit produced by the action of the tooth of the signal wheel causes the receiver to draw a dash on a paper tape. The number of teeth and their spacing will then determine the signal recorded at the central station. For example, - - - - - - - - - - is read as "signal 324," and its identity is immediately known through reference to the central station "assignment list."

Fig. 9 shows the transmitting circuit which comprises the wiring and necessary elements to connect the transmitter

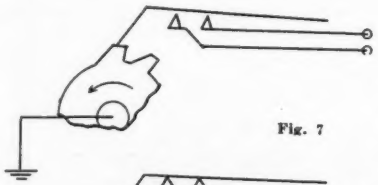


Fig. 7

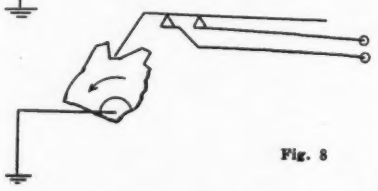


Fig. 8

located at the supervised plant to the receiver at the central station. The entire arrangement is called the McCulloh circuit after its inventor. This type of circuit has been commonly used for many years in the signaling field. From the transmitter, or a number of them, the wires run direct to the central station where all the circuit elements except the transmitters are located. The outstanding advantage of this circuit is that it allows the maintenance of supervision in spite of a broken or grounded wire, or with a combined break and ground.

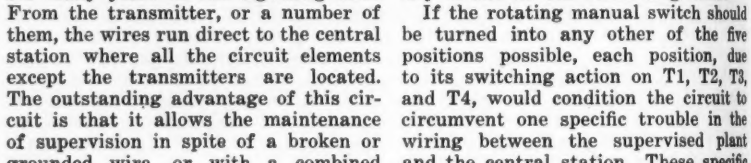


Fig. 9

Use of Multiple Transmitters

A considerable number of transmitters can be connected in series to the same circuit. As each transmitter is recognized by its own characteristic signal as explained above, it is an easy matter to determine which transmitter has "run in," and likewise, what has happened at the supervised premises. Thus, one line can handle many signals of different origin. The transmitter's sequence of ground-break-normal, previously explained, results in the following:

When the ground impulse occurs, relay G is shunted and de-energized. Its contact G1 will transfer to the left, complete a circuit through the pilot lamp and the latter will light.

Immediately following the ground impulse, a break impulse occurs. This causes relay N to de-energize, relay G remaining de-energized. When relay N de-energizes, its contact N1 transfers to the left and completes the circuit to the register which will mark a dash on a paper tape for each impulse it receives.

The McCulloh arrangement permits conditioning of the circuit to respond to signals in the event of line fault conditions.

There is a rotating manual switch or its equivalent in the central station with contacts which are designated in Fig. 9 at T1, T2, T3, and T4. The switch can be rotated into five different positions, each of which changes one or several of the four contacts by opening, closing, or transferring them. The position shown in Fig. 9 corresponds to the normal situation without any defect in the connecting lines.

If the rotating manual switch should be turned into any other of the five positions possible, each position, due to its switching action on T1, T2, T3, and T4, would condition the circuit to circumvent one specific trouble in the wiring between the supervised plant and the central station. These specific troubles are a grounded wire, a broken

wire, a broken wire grounded on the live side, and a broken wire grounded on the grounded side.

Assume the case of an accidental ground. The relay G will be shunted out by the ground. As a consequence, contact G1 will transfer to the left. The pilot lamp will light up, giving an indication of the trouble. The manual switch is then rotated to a position where T1 closes to the right, T4 closes, and T2 and T3 remain in the position as indicated in Fig. 9. As T1 closes to the right, relays G and N become connected in parallel and both are energized through the live wire and the ground return.

In case of a signal from one of the transmitters, either the N or the G relay—which one depends on the location of the ground—would de-energize with each break impulse caused by the signal wheel. Contacts G1 and N1 will transfer with each impulse and reproduce the coded signals in both receiver and pilot lamp as under normal conditions.

Similar re-conditioning switching is done in other trouble conditions. For example, in case of a break in the lines connecting the supervised plant and the central station, the manual rotary switch is turned to transfer T1, T2, and T3 to the closed position on the right and close T4. The break would have de-energized relays N and G, the pilot lamp would have lighted up and the receiver would have started to run without giving a coded signal, drawing a continuous line on the paper tape.

The switching action would stop the receiver, and disconnect the pilot lamp. Relays N and G would then be connected in parallel. In case of a signal from one of the transmitters, either the N or the G relay—which one depends on the location of the break in the wire—would energize with each ground impulse caused by the signal wheel, and as a consequence the signal would be reproduced by the receiver and the pilot lamp in the central station.

Two other possible troubles in the connecting lines were mentioned above. Re-conditioning of the circuit is possible by switching actions similar to the ones described above.

The McCulloh circuit permits receipts of signals even under faulty line conditions, until normal conditions are restored. The McCulloh circuit is nothing new. It has been employed for many a decade, but its usefulness is obvious especially for industrial process

Continued on page 449

Future *of* Graphic Panel *in* Process Control

By E. J. GRACE, JR., Sun Oil Company

AFTER two years, the impact of the graphic panel on the instrument field is still being manifested in announcements of new miniature pneumatic recorders, controllers and panel accessories peculiar to graphic installations.

In all units being offered, speed of response is stressed, together with "dead beat" controller action.

Undoubtedly, the designers of this equipment have made a great contribution to the field of measurement and control. Reports from most small process installations have been uniformly good, but large units have occasioned compromises in the efficiency of the control system desired.

Reports of proposed installations requiring upwards to a million feet of tubing in one plant and graphic boards over a hundred feet long indicate that possibly the system is being misapplied for want of equipment that will meet the needs of these modern industrial units.

Regardless of how fast a pneumatic system may respond, it still suffers in comparison with electrical transmission and response.

Consider communicating between New York and San Francisco. If it were possible to transmit sound through air that far, it would require about 5 hours for a signal in one direction. A yes and no conversation would require 10 hours. If the sound vibrations were transmitted through steel, it would require 40 minutes for the same round trip. With electrical transmission the transit time is cut to less than 0.04 second.

Cognizant of the fact that the above illustration involves the transmission of a condition and does not involve the transportation of any volumetric component, then the use of a pneumatic transmission system, which does require a volumetric change, becomes very circumscribed in its application.

It appears that the industrial instrument industry has not properly analyzed the requirements of modern processes. Equipment that has been designed for control of an individual process variable has, with a great deal of ingenuity, been converted into an arrangement whereby all process variables can be adjusted from a central point by an operator. This seems to be the end of the line as far as the process is concerned. Certainly to attempt to use these pneumatic components in a completely automatic control system; wherein all related variables are compared and the necessary over-all correction made in the process to maintain the final end product specifications, would result in chaos or worse.

A complete electrical system for measurement and transmission of process variables is definitely the medium required for a complete integrated system of process control.

The results obtained in other fields with electric controls illustrate the fallacy of industrial instrumentation today. The author refers to gunnery control, rocket direction or even the more prosaic job of high-speed elevator control. Certainly the complications and precision required in the fields mentioned are equal to any industrial demands.

In projecting such an electric system, we must discard many of our basic measuring tools and devise new ones. The thermocouple and the resistance thermometer may be retained since they are electric, but thermistors and allied types of temperature sensitive units should be thoroughly investigated.

The bourdon tube with an electric conversion unit attached does not seem to offer much promise. A more sensitive device is required which conceivably might be used in pairs for flow measurement or differential level determination. In an electrical system corrections for gravity and temperature changes are quite simple.

In the final measuring unit our deflection or null balance instruments are much too slow. Electric computers available today offer unlimited speed and great accuracy. Even the simple electric calculator in use in office work possesses greater speed and accuracy than any industrial measuring device available.

In the control circuit, we might borrow the pulse system from radar and position a unit in the final controlling element with high speed pulses. This would permit the use of pneumatic control valves with an electric pilot and eliminate the high cost of all-electric valve units.

With such a system, the introduction of a scanning system would permit the control of a hundred variables using only one central computing controller, assuming a scanning rate of 25 variables per second.

In such a system, continuous records of process variables do not seem to be necessary, but a supplementary monitoring system would be used to print a record of date and time that any variable departed from preset limits.

To obtain full advantage of such a system, quality measuring devices must be developed that will insure uniformity of the end product and maximum efficiency of the complete process as established by the physical condition of some unit in the entire plant, such as a fouled exchanger, plugged line, etc.

The cost of such a system should be much less than the present pneumatic units involved which are a very poor substitute for the equipment so urgently required by process industries today.

*Paper presented before the "Philosophy of Panel Design" Symposium of the Newark Section, Instrument Society of America, Newark, N. J., April 3, 1951.

Fig. 1

Instrumentation *and* Automatic Control Course *for* Mechanical Engineers

By MILLARD H. LaJOY, Assoc. Prof., Mechanical Engineering Dep't, University of Minnesota

IN THE planning and organizing of a special course on instrumentation and automatic control, cognizance must be given to the contents of all existing courses in the school. While the curricula may not show any teaching along this line, time is usually devoted to instruments in connection with other courses. For example, several laboratory courses in mechanical engineering include work on temperature, pressure, flow, viscosity, speed, gas analysis, and other measuring methods. Although instrumentation is secondary here, the student devotes some time to the techniques of measurement. The extent of time devoted to the measurement phase of instrumentation should be carefully investigated in order to plan what time must be allotted to sensing elements, indicators and recorders in a proposed new course.

On the other hand, the automatic control phase of this subject usually will not have been covered in any other course in the curricula. The teaching of automatic control is new in our technical schools. Therefore, the part of this teaching that will require most of the work and new equipment will be on control.

The purpose of this article is to outline the results of setting up and teaching a course on Instrumentation and Automatic Control in the Mechanical Engineering Department at the University of Minnesota. This course was first inaugurated by the author three years ago. Since then, approximately forty different classes involving over six hundred students have taken this course. The enthusiasm and interest shown by the students have been the highest ever experienced by the author in ten years of teaching. This is satisfaction enough for the efforts one must put forth to develop a course of this nature in the college curricula.

Course Description and Outline

The course entitled "Industrial Instrumentation and Automatic Control" is offered only to seniors. It is three quarter credits and is conducted on a two-hour lecture and a three-hour laboratory per week basis for eleven weeks.

An outline of this course by weekly coverage for eleven weeks is shown below. This outline deals primarily with automatic controls because mechanical engineering students receive good training on measurements in other laboratory courses in the curriculum.

1. Domestic control circuits including electric on-off, electric proportional and pneumatic proportional control.

2. Terminology covering proposed standard of terms and the corresponding old terms.

3. Mathematics of control, graphical representation of control effects, calculations of hypothetical cases in control work.

4. Principle of operation and circuit analysis of pneumatic-type controllers including proportional, floating and rate control effects.

5. Principle of operation and circuit analysis of hydraulic type control-

lers including proportional and floating control effects.

6. Principle of operation and circuit analysis of electric type controllers including proportional and floating control effects.

7. Lag coefficients and process time constants.

8. Process analysis of single and two capacity systems. Use of electric and hydraulic analogies.

9. Controller settings as related to process analysis including empirical procedures available.

10. Final control elements.

11. Typical applications of automatic controls. This usually involves a field trip to some plant.

The above outline sequence has been arrived at after considerable experimentation with the different classes during the past three years. It gives the new student a gradual introduction to the understanding of the control principles.

During the second week, when terminology is covered, it is important that all old terms with their associated new terms be emphasized. For example, on-off control is also known by two-position or open and closed; or rate response is also known by derivative, pre-act, booster or anticipatory response, etc. This association of terms is a prerequisite to any intelligent reading of the literature or manufacturers' catalogs.

During the third week, when the mathematics of control is covered, it will be helpful to improvise a group of hypothetical problems. The student will be able to understand the theory of proportional, proportional-speed floating and rate control effects more thoroughly if he is guided in the actual solution of problems. While there are no problems in the available textbooks, they can be prepared easily. Some samples of such problems are covered in Chapter four of "Principles of Industrial Process Control" by Eckman.

The coverage in succeeding weeks on pneumatic, hydraulic, and electric control circuits followed by studies of process characteristics should not involve difficulty. Existing books cover these subjects quite well.

Text and Teaching Material

Some of the books available for reference on automatic control and possible text include three from McGraw Hill: "Industrial Instruments for Measurement and Control" by Rhodes, "Automatic Control Engineering" by Smith, and "Instrument and Control Manual for Operating Engineers" by Feller; one from Wiley: "Principles of Industrial Process Control" by Eckman; and one from Delmar Publishers: "Instruments and Process Control."

The text used by the writer is "Industrial Instruments for Measurement and Control" by Rhodes. It combines both the instrumentation and automatic control into one book. However, a list of reference reading is given for the students in the other books. These are reserved for the students in the Engineering Library. In addition, manufacturers' catalogues are available for reference during and in conjunction with the laboratory experiments.

Laboratory Experiments

It is desirable to have as many services as possible in the laboratory. Over each work area it is desirable to have electric outlets, filtered air supply with a pressure reducer valve, vacuum outlet, water supply outlet, and a gas outlet. This will provide complete flexibility for any future addition or changes one usually will make in the development of good experiments. Also, it provides a facility for carrying on research however varied it might be.

There are at least two thoughts on what would constitute a suitable laboratory. One is to develop some pilot plant process and devote all of the laboratory time to a complete study and analysis of it. The other is to develop a group of small self-contained experiments covering a wide range of instruments and controls. There are good arguments for each of the above plans. The latter plan was used by the writer. It gives the student an acquaintance with a greater variety of equipment. Fig. 1 shows the present state of this laboratory. Included in the laboratory course are twelve experiments on domestic control circuits and nine experiments on industrial instruments and controls.

Three reasons for including domestic circuits in the laboratory are: First, many mechanical engineers go into fields where these circuits find considerable use. Second, domestic controls are usually the simpler on-off circuits and the students can begin their laboratory work with these experiments which require a minimum amount of preparation in the lecture room. He learns in his beginning laboratory work the scheme of planning a complete automatic control circuit. For example, he begins to recognize the two basic parts of a system, such as the primary measuring element and the final control element. Then he studies the need of including between these two basic items many forms of limit or emergency controls. Third, on-off control is one of our most widely used modes of control. It is highly sensitive and comparatively inexpensive. These facts should be stressed in the teaching.

Students are started on industrial instruments and controls after three weeks of lecture. At this time he has covered thoroughly the terminology and the available control effects. Thus, he is prepared to work experiments involving all control responses. One of the principal laboratory experiments necessary is a small scale simulated process under automatic control by a single-, two-, and a three-response controller. Instrument and control manufacturers will be of considerable help here, either in supplying one or in recommending a suitable setup. The writer procurred one from the Taylor Instruments Company which involves a process under automatic control by a three-response pneumatic controller. This equipment has means of adjusting load and process time constants. With this setup it is possible to study the behavior of a variety of processes under automatic control by a proportional, a proportional plus reset, proportional plus rate, and a proportional plus reset plus rate controller. With at least one laboratory experiment of this nature one can begin to cover industrial automatic control circuits effectively. More experiments of this type can be added as the course is developed. For example, the author has under construction a small scale furnace process to be operated by a three-response controller. In addition, a third such setup involving a liquid level process is being designed.

Aside from the need of experiments on small scale simulated processes, one will have to round out the laboratory with additional equipment. As shown in Fig. 1, a good variety of instruments and controls are provided. Other experiments included are a simulated pressure application under automatic control by an industrial electro-vane on-off controller, a sixteen point electronic potentiometer connected to a temperature gradient study, a telemetering system connected to a water pressure application and miscellaneous instruments such as temperature recorders and flowmeters which are used for instrument construction and design studies.

Conclusion

With the rapid increase in use of automatic controls today, even to the point of operating entire plants automatically with "graphic panels," the colleges and universities must get into the picture. Training our technical graduates on automatic controls is now an obligation. In building up this training program, we will need help from the manufacturers as well as from each other.

The plan of laboratory instruction used in the Mechanical Engineering Department at the University of Minnesota, as covered in this paper, has proved most effective. The use of a wide variety of self-contained experiments has made it possible to assign exactly two students per group. This factor has been a great help to the success of the course. Because of the keen student interest and enthusiasm one is able to cover rapidly and efficiently the basic concept behind automatic control systems.

Acknowledgements—The author wishes to acknowledge the help and cooperation received from the following instrument manufacturers: Minneapolis-Honeywell, White, Rogers, Perfex, Taylor and Bristol.

Sweep-operated Oscilloscope Beam Blanker *with* Tissue Stimulator Synchronizer

By A. L. DUNN, Ph.D., A. R. McINTYRE, Ph.D., M.D. and A. L. BENNETT, Ph.D., M.D.
Dep't of Physiology and Pharmacology, Univ. of Nebraska College of Medicine, Omaha, Nebr.

THIS article presents the design and specifications of an instrument with which photography of single trace patterns on the oscilloscope has been made possible without the fogging of sensitized paper or film otherwise encountered with prolonged background illumination. The instrument also provides synchronization of a tissue stimulator with the oscilloscope sweep.

To achieve this result the instrument was designed to be controlled by the sweep circuit and to blank the oscilloscope beam except for the actual interval it traverses the screen. It also provides a pulse which, with controlled delay, triggers a thyratron type tissue stimulator. This system eliminates the necessity of precise timing of the camera shutter which may be left open while the sweep is manually tripped. We have found it convenient to use a switch on the camera shutter to trip the sweep.

A method for blanking the oscilloscope beam by the use of a "flip-flop" circuit has been described in the literature.[1] This earlier system depended on external triggering impulses to release the beam and to blank it subsequently. Several laboratory type oscilloscopes have beam-blanking circuits incorporated but the usual, moderately priced instruments are not so equipped. The beam blanking circuit which we have developed can be attached to any oscilloscope and with proper choice of circuit constants can be adapted to blank at any desired rate and to delay release of the sweep by any required interval. Fig. 1 shows the completed instrument; the circuit diagram and constants are given in Fig. 2. The beam blanking section of the circuit is described in detail elsewhere,[2] and briefly herewith. It consists essentially of an isolating amplifier (V_1) driving a cathode follower (V_2) through a resistance-capacity delay circuit. Condenser C_6 in the cathode circuit of V_2 further delays the building up of the pulse which trips the "flip-flop" tube V_3. Tube V_4 couples the "flip-flop" tube to the grid of the c-r. tube and at the same time provides for the introduction of a dotting signal at Z if desired.

The operation of the instrument is straightforward. When R_{13} is adjusted properly and no sawtooth wave is coming through from the oscilloscope sweep circuit, the right side of V_2 is conducting, which causes the potential at the plate of this section to assume a relatively low value. This potential appears at terminal G of the output which is connected to the c-r. tube grid, making the grid about 100 volts negative with respect to the cathode whose potential is maintained at that of point X in Fig. 2. The beam is thus blanked. Release of the beam is effected by the negative segment of the oscilloscope sweep saw-

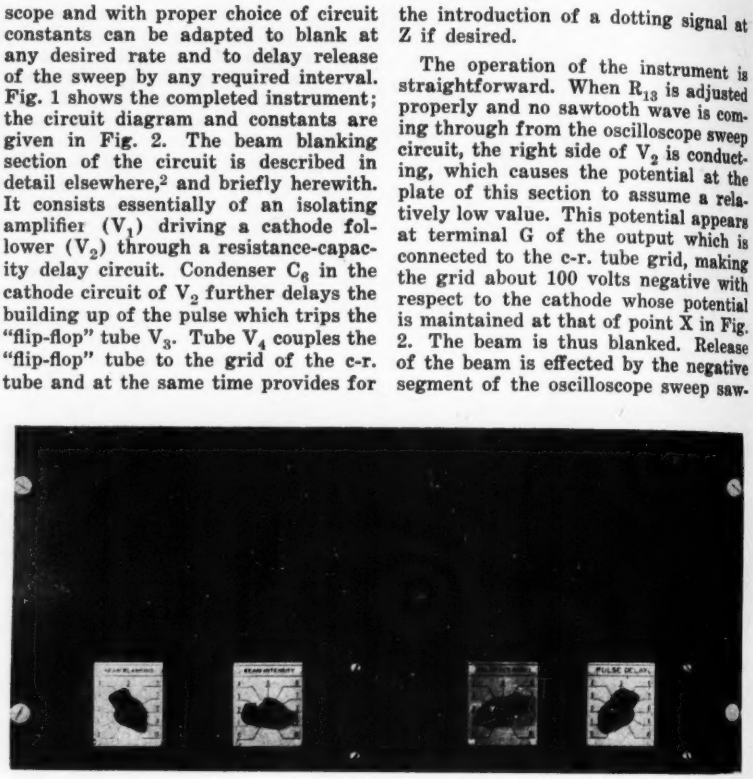
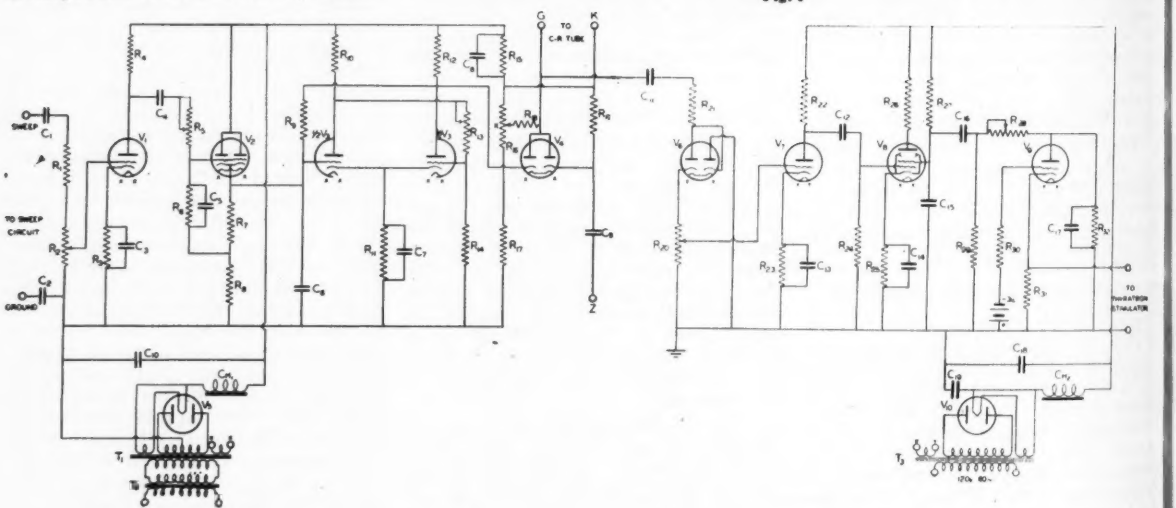


Fig. 1



$R_{1,29}$ - 1 meg. ½w.
$R_{2,9,20}$ - 500K lin. pot.
R_3 - 2.5 K ½ w.
$R_{4,17,22}$ - 47K 1 w.
R_5 - 750K lin. pot.
R_6 - 750K ½w.
R_7 - 4K 1 w.
R_8 - 8K 1 w.
R_9 - 200K 1w.
$R_{10,12}$ - 22K 1w
R_{11} - 10K 1w.
$R_{14,15,16}$ - 100K ½w.
R_{15} - 5K 1 w.
R_{18} - 25K lin. pot.
R_{21} - 2.0 meg. ½w.
R_{23} - 1500Ω ½ w
$R_{24,32}$ - 0.47 meg. ½ w
R_{25} - 200Ω 1w.
R_{26} - 8K 10 w
R_{27} - 130K 2 w.
R_{28} - 100K lin. pot.
R_{30} - 68K ½ w
R_{31} - 500Ω ½ w.
C_1 - 0.01 mfd. 2000 v.
C_2 - 0.5 mfd. 2000 v.
$C_{3,13,14}$ - 25 mfd. 25 v.
$C_{4,12}$ - 0.1 mfd. 600 v.
C_5 - 0.05 mfd. 600 v.
C_8 - 4.0 mfd. 600 v.
C_7 - 0.25 mfd. 600 v.
C_8 - 0.5 mfd. 600 v.
C_9 - 0.006 mfd. 2500 v.
$C_{10,18,19}$ - 40 mfd. 450 v
C_{11} - 0.01 mfd. 2500 v.
C_{15} - 8 mfd. 450 v
C_{16} - 2 mfd. 600 v.
C_{17} - 0.2 mfd. 600 v.
$C_{H1,2}$ - 4 Hy. choke
T_1 - pwr. trans. 700 v. CT. 40 ma.
T_2 - 1:1 isolating trans.
T_3 - pwr. trans. 700 v. CT. 90 ma.
$V_{1,7}$ - 6J5
$V_{2,3}$ - 6SN7GT
$V_{4,6}$ - 6H6
$V_{5,10}$ - 80
V_8 - 6L6G
V_9 - 884

Fig. 2

tooth. Potentiometer R_2 controls the input from the oscilloscope sweep circuit and should be adjusted to give adequate drive to V_1 but not enough to cause it to draw power. The timing circuit made up of C_4, C_5, R_5 and R_6 controls the duration of the beam release interval by varying both the amplitude and build-up time of the positive pulse on the grid of tube V_2. When the voltage across C_6 rises sufficiently the left side of V_3 suddenly conducts, and the right side becomes nonconducting. Immediately the potential at this plate rises to approximately the same value as that of point X in Fig. 2, releasing the beam since the negative bias on the c-r. tube grid falls to a value determined by the position of the intensity control R_{16}. When the positive segment of the sweep sawtooth comes through the blanking circuit, the sequence of events is reversed.

The synchronized trigger pulse which controls the thyratron tissue stimulator is in turn controlled by the pulse which releases the beam. By the use of a delay circuit the stimulus artefact and the resulting tissue response pattern can be positioned at any desired point on the oscilloscope trace.

A double diode limiter (V_6) serves to clip off any negative pulses coming through from the blanking circuit proper. Tube V_7 amplifies the positive pulse, feeding it to V_8 which is a power amplifier supplying a thyratron (V_9) through a delay network (C_{16}, R_{28}). The pulse which is developed across R_{31} is used to trigger the tissue stimulator which is of the thyratron type.

A word of caution is in order regarding insulation. All parts of the circuit to the left of condenser C_{11} are essentially at the potential of the cathode and control grid of the oscilloscope tube. Since it is conventional to operate the second anode and the deflection plates at or near ground potential, the grid

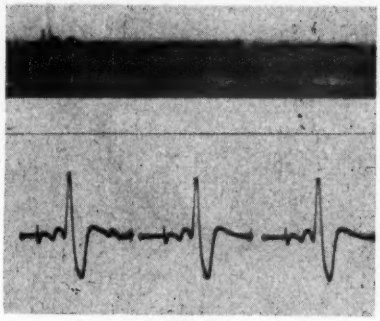


Fig. 3

and cathode are several thousand volts negative. All components of the instrument to the left of C_{11} were assembled on a bakelite panel which was set into a space cut in the top of the chassis. An isolating transformer (T_2) used in conjunction with a small power transformer (T_1) serves to insulate this portion of the instrument from the power line. Condensers C_1, C_2 and C_{11} are of ample voltage rating. The balance of the circuit can be grounded and treated in the usual manner.

The presence of capacitance in the grid-cathode circuit to which this instrument is attached will affect the shape of the square wave from the "flip-flop" circuit so that the intensity of the trace will vary markedly during the period when the beam is released. The ideal situation is obtained with a pure resistance network supplying the c-r. tube grid bias, and on which the bias from the beam blanker is superimposed.

The present version of the instrument was provided with standard Amphenol fittings so that it could be attached to any one of several oscilloscopes as the need arose. Removal of the device from an oscilloscope simply leaves it operating in the conventional manner. The delay circuits can be modified to suit individual requirements. The specific work for which this instrument was constructed required trace durations ranging from 0.001 to 0.020 seconds with a repetition rate of three traces per second. The delay introduced by the tissue stimulus synchronizer is adjustable up to 0.01 seconds.

The contrast between the system as described and an older method where no beam blanker was used and the stimulus and the sweep were not synchronized is shown in Fig. 3, which is a photograph made on moving sensitized paper of repeated three-per-second sweeps.

REFERENCES

(1) Richter, Walter, *Electronics*, Vol. 17, Sept. 1944, page 128.

(2) Dunn, A. L., McIntyre, A. R. and Bennett, A. L., *Electronics*, Vol. 23, Sept. 1950, page 94.

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Measurement *of* Induction-motor Rotor Temperatures

By DR. WILLIAM A. THOMAS, Associate Professor of Electrical Engineering, Case Institute of Technology and RAYMOND J. HORVAT, Electrical Engineer, Auburn Engineering Company

Introduction

DESIGNERS of electrical machinery, by better use of available materials, constantly endeavor to improve their product. The new designs are such as to give reduced cost, weight, and size, as well as higher quality and improved performance.

To evaluate designs properly the temperature distribution throughout the machine must be known under actual operating conditions. Accurate means of temperature measurements for the rotating element when in operation have not been available.

Thermometers can be used on accessible portions of the stationary elements but are impractical for the rotating elements. Thermocouples have been widely used and have given accurate readings except for the rotating parts. Where the connections to the thermocouples are made through slip rings serious errors are introduced by the variable contact characteristics.

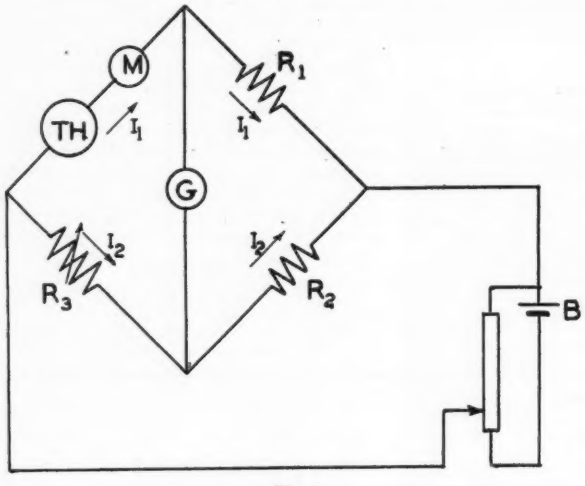

Fig. 1

The use of the thermistor device for determining rotor temperatures seems to offer real promise as an accurate, simple, and practical means. Over the normal operating range of electrical machinery the accuracy of the device indicates an apparent precision of ± 0.2 C. It is so small as to be fitted into the rotor without disturbing present spatial positions and its resistance characteristics are such as to eliminate slip-ring errors. Simple calibration means are available for thermistors.

Apparatus

A schematic diagram of the temperature measuring apparatus is shown in Fig. 1. The temperature-sensitive element of the circuit, is a Western Electric Type D-177232 Thermistor.[1,2]

This type thermistor is a tiny glass-coated bead of a semi-conducting material having a resistance of about 100,000 ohms at room temperature. Its temperature coefficient of resistance is − 4.6 (percent per deg. C. at 25 C.). Its resistance at 80 C. is only 6,000 ohms. The thermistor bead with its glass coating is about 0.1 centimeter in diameter.

The thermistor is connected as the variable element in a Wheatstone bridge as shown.[3] A potentiometer arrangement with a 1.5-volt #6 dry cell provides about 1.0 millivolt for the bridge. This potentiometer voltage control is important to keep the current in the bridge and thermistor element to a low value. A microammeter is connected in a series with the thermistor element and the current held to less than 2.5 microamperes.

Each of the platinum leads from the thermistor was silver soldered to a length of shielded wire. The soldered parts and the uninsulated platinum leads were coated with glyptal varnish. The complete assembly was inserted into the rotor windings within the open space between the slot and the windings. In this position the thermistor was in relatively good contact with the winding surface. The leads were then brought out along the shaft to slip rings and brushes.

Test Apparatus

The motor used for this test was a three-phase wound-rotor induction motor. The secondary terminals were disconnected from the slip ring and were connected together on the rotor. The motor was then operated as a squirrel-cage induction motor. This was done to permit the use of the slip rings for the electrical circuit to the thermistor. The brush contact resistance is negligible compared to the resistance of the thermistor.

Calibration

The Wheatstone bridge was one designed for high sensitivity over the entire range of the thermistor resistance encountered. Since at the lower resistance values, the resistance change is slight for a comparative large change

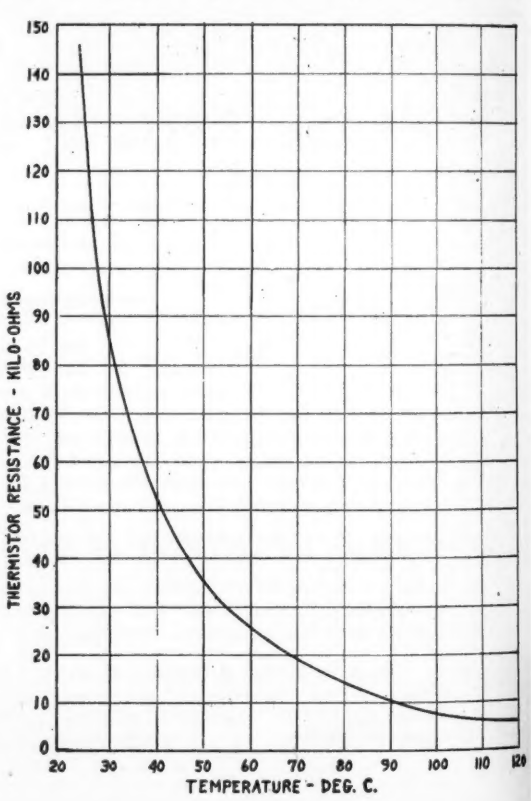

Fig. 2

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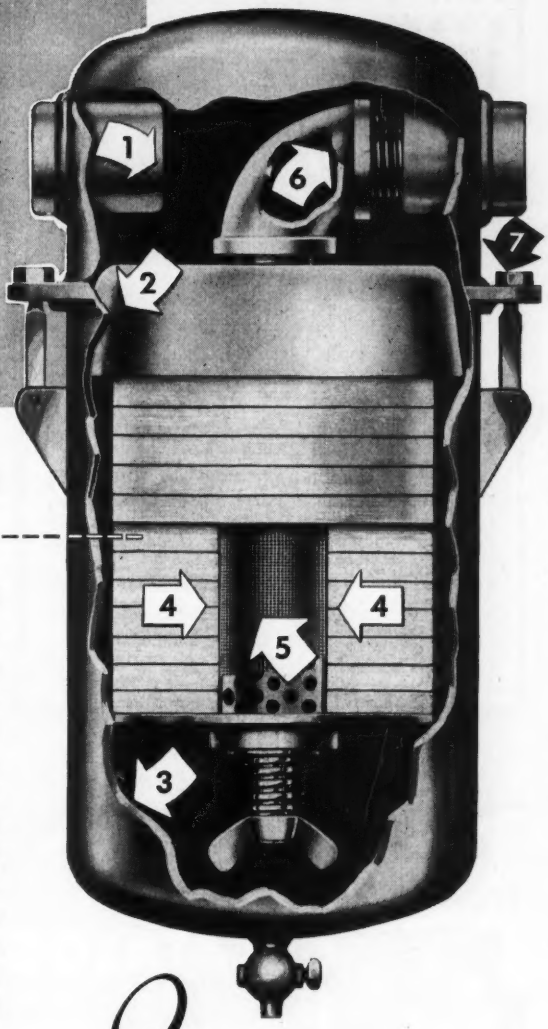

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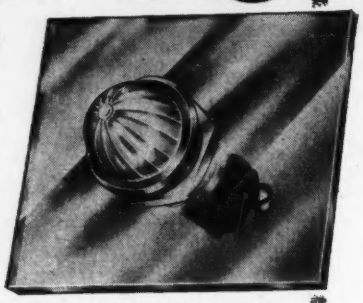

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in temperature it was necessary to choose this point as the one for maximum bridge sensitivity.

The thermistor temperature was raised to about 85 C. and the potentiometer was adjusted so that a current of 2.5 microamps passed through the thermistor for a null reading on the galvanometer. The resistance arms were then chosen so that a maximum of potential difference existed across the galvanometer input for the given applied voltage. The applied voltage was never varied after once having been adjusted.

The thermistor was calibrated with the microammeter in series with it. Since the meter resistance was constant and it remained in the circuit at all times its presence does not affect the temperature readings.

Actual calibration was accomplished by placing the entire rotor, with thermistor and suitable leads installed, in an electrically-controlled oven. The oven temperature was varied over the anticipated heating range and the thermistor resistance readings were taken at several points over the temperature range to be tested.

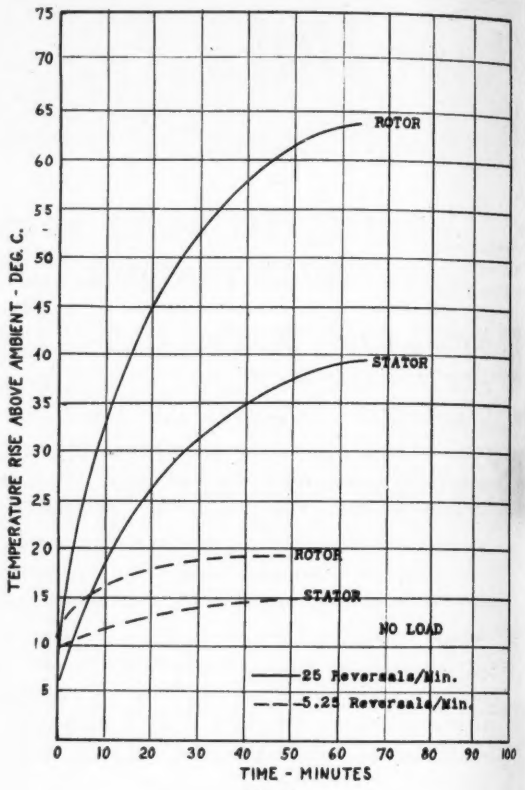

Fig. 3

The oven temperature was held constant for several hours at each of the points taken in order for the rotor temperatures to stabilize to the indicated thermometer value. By following such a procedure over the entire range of expected temperature measurements a calibration curve of the thermistor was obtained. For the thermistor used in this test the calibration curve is shown in Fig. 2.

Motor Temperatures

In order to apply the thermistor temperature method to a typical severe motor test it was decided to use a plugging condition. Plugging consists of a full voltage reversal of the motor from full speed ahead to full speed reverse. It represents a condition causing severe heating in the motor especially in the rotor and is a practical case in that it occurs innumerable times in applying motors to automatic machines.

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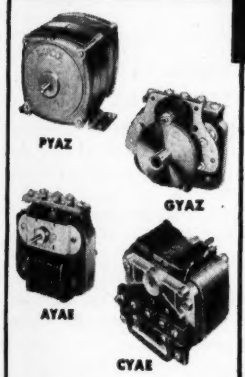

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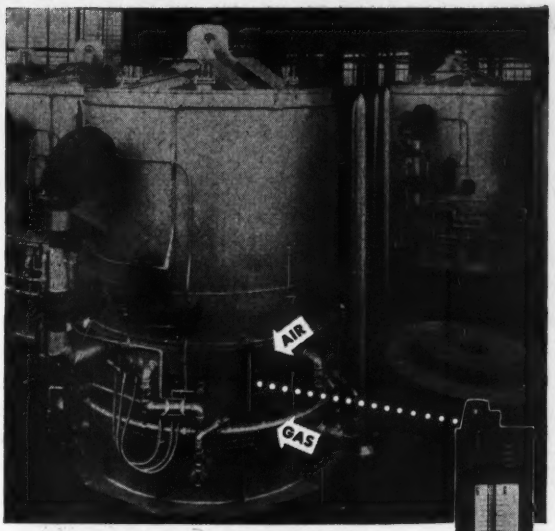

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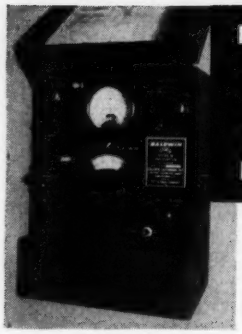

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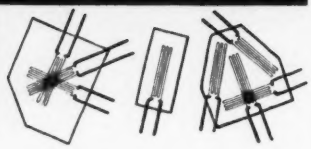

Designed for use with SR-4® gages: gage factors of 1.77 to 2.20. Battery-operated; converter available. Ask for Bulletin 312.

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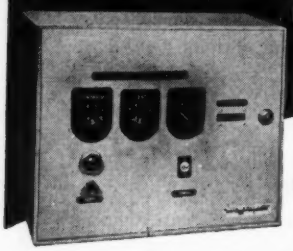
Counts Batch Quantities **Automatically**



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Stops over-count losses and under-count complaints
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alone and with added flywheel. The results of these tests are shown in Figs. 3 and 4.

These curves show actual time-temperature curves for the rotor when operating under the test. The curves are smooth and indicate the absence of any extraneous operating effects. No comparison was made with other measuring methods as they are impractical for rotor tests.

Accuracy of Results

After repeated use, the thermistor showed a high degree of constancy. Repetition of the tests indicated we were able to duplicate values consistently with no apparent aging effect.

From the curves plotted the indicated accuracy is greater than ± 1.0 C. The calibration curve shows an accuracy of

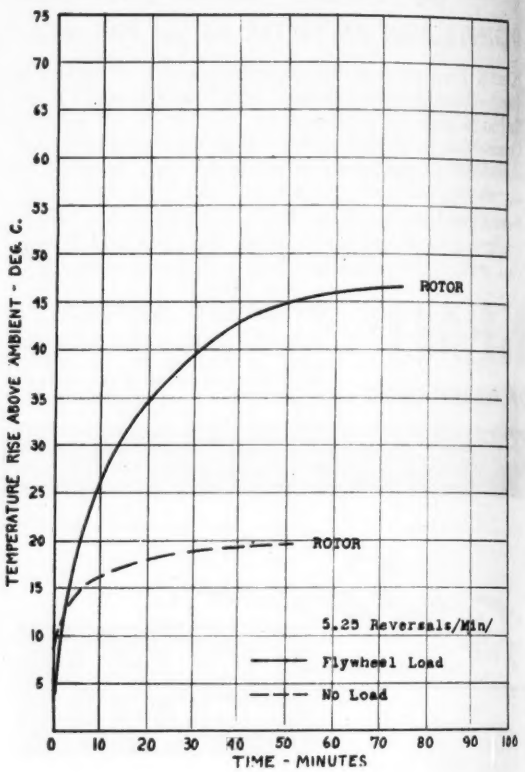


Fig. 4

± 0.2 C. A brush resistance variation and extraneous pick-up voltage caused a slight variation in the actual test results preventing the realization of the full accuracy from calibrated values.

Limiting thermistor current to 2.5 microamps reduced the thermistor heating to a negligible value without introducing additional error. The brush resistance was negligible compared to the thermistor resistance but the variation of temperature measurements indicated the possible effect of brush contact variation and indicates the advisability of using a low resistance contact.

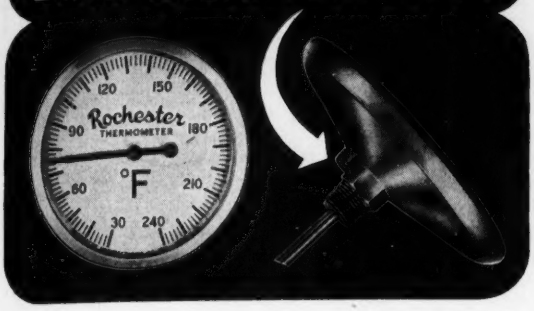
Conclusions

The use of thermistors for measuring electrical machinery rotor temperatures is a very practical additional tool for motor designers. Circuit, calibration, and use of the thermistor for this purpose are explained. This test method which is simple and practical will give actual rotor temperatures within ± 1 C. and with extreme care in the test could be given to ± 0.2 C.

References

1. K. P. Dowell, *Electrical Manufacturing*, August, 1948.
2. J. A. Becker, C. B. Green and G. L. Pearson, *A.I.E.E. Transactions*, June, 1946.
3. P. G. Ecker, J. Blum and C. W. Hiatt, *Review of Scientific Instruments*, November, 1949.

RECALIBRATE on the job— Rochester DIAL THERMOMETERS



Accidents are bound to happen . . . like dropping or banging a thermometer sufficiently hard to make readings inaccurate. This could result in costly production errors. To eliminate this possibility, Rochester now offers a new bi-metallic Dial Thermometer with screw adjustment permitting recalibration on the job! Simply put the instrument in boiling water or other known temperature and reset indicator. Better order today. Send for Catalog No. IT-650, Rochester Manufacturing Co., Inc., 85 Rockwood St., Rochester 10, N. Y.

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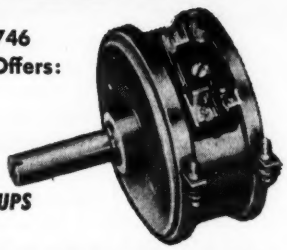

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The new potentiometer is supplied with linear or non-linear windings to meet your specifications. Accuracy is high, ±.5% (linear), ±1.0% or better (non-linear). Torque is extremely low, 1.5 oz-in. per cup max. Dimensions: diameter 1.750 in.; length .800 in. ±.009 in. (added length per unit when ganged, .580 in. ±.002 in.) Case is of grey anodized aluminum.

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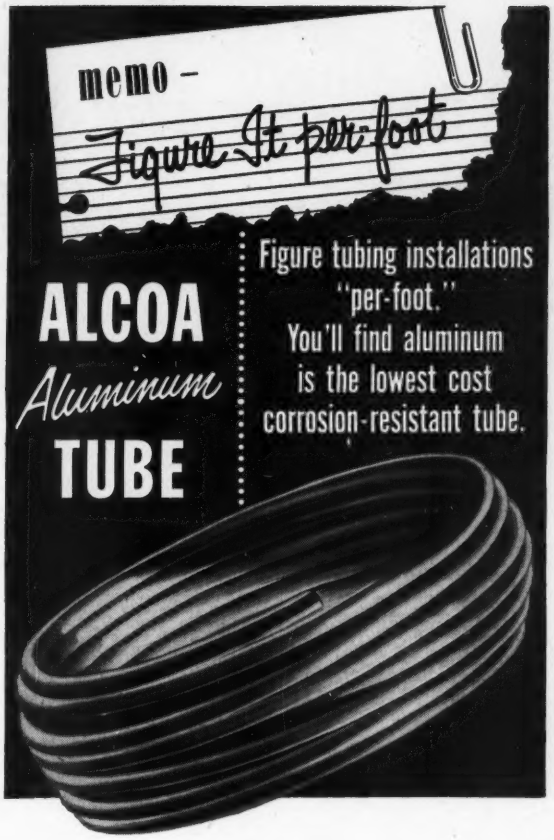

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ALCOA *Coiled Tube* **ALUMINUM**

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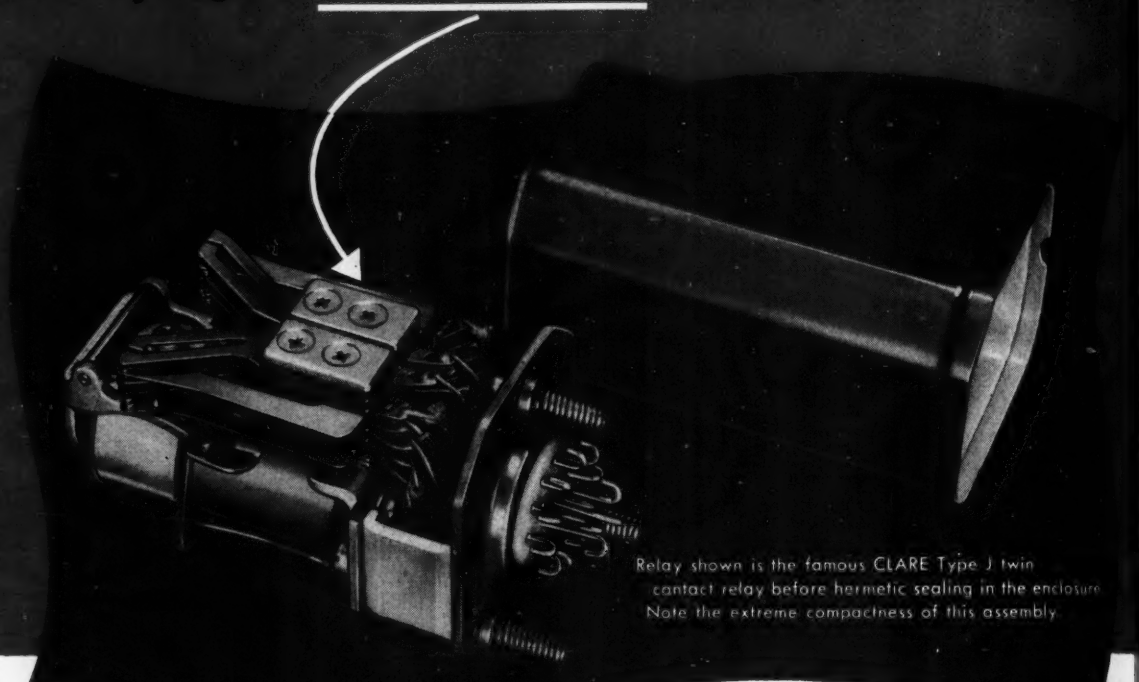
Good Hermetic Sealing is important—
Specifying a CLARE RELAY is important, too!



Relay shown is the famous CLARE Type J twin contact relay before hermetic sealing in the enclosure. Note the extreme compactness of this assembly.

HERMETIC sealing, as practiced by C. P. Clare & Co., provides the most perfect seal ever devised to insure ideal relay performance under all conditions.

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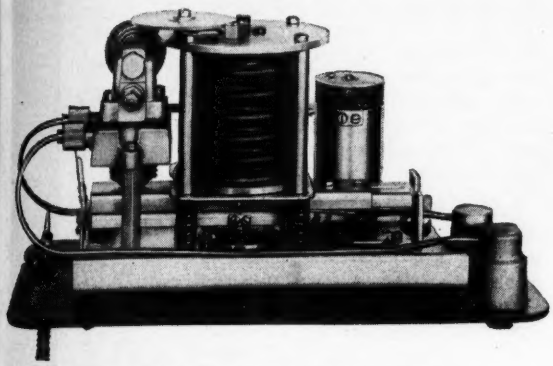
Write for 36-Page Clare Bulletin No. 114

CLARE RELAYS

First in the Industrial Field

DYNAMIC ACCURACY means more today than ever before!

Accurate Measurement of changing temperatures and pressures is the vital first step in instrumentation, whether indicating, recording or controlling. Today, TRANSAIRE* Transmitters set new standards for sensitive and accurate measurement.



TEMPERATURE:

Taylor TRANSAIRE Temperature Transmitter with Speed-Act* lets you measure and transmit smallest temperature changes up to 1000 feet with great accuracy! The *only* temperature transmitter that gives you:

1. DYNAMIC ACCURACY—which means the accuracy of an instrument in measuring changing or dynamic conditions. TRANSAIRE Dynamic Accuracy is unparalleled. Solves the problem of process engineers who realize that an instrument accurate to a fraction of a degree in measuring static conditions can be in error by many degrees when temperature is changing.

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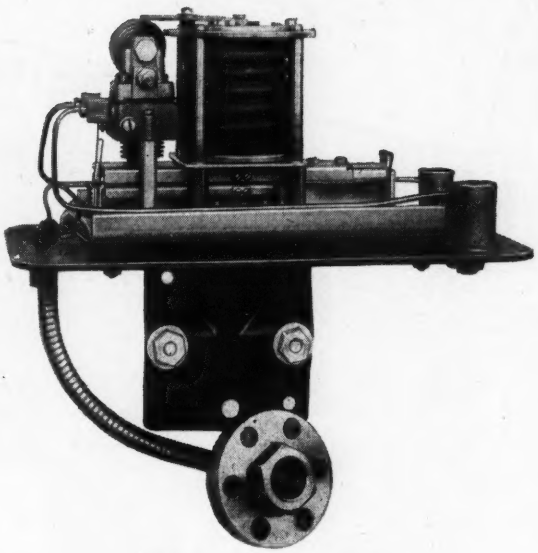
TRANSAIRE is the first step in Taylor's TRANSET* Control System. Step No. 2 is the Taylor TRI-ACT* Controller. Step No. 3 is the Taylor TRANSET Recorder or Indicator. All three combine into the already famous complete Taylor TRANSET Control System. **Write for Bulletin 98097.** Taylor Instrument Companies, Rochester, N. Y., and Toronto, Canada.

*Trade-Mark

Instruments for indicating, recording and controlling temperature, pressure, humidity, flow and liquid level.

Taylor's Centennial ACCURACY FIRST SINCE 1851



PRESSURE:

Taylor TRANSAIRE Pressure Transmitter with narrow range spans lets you measure and transmit minute pressure changes up to 1000 feet. Works on simple force-balance principle. Accurate to ½% of the selected short range span (*conventional devices are only accurate up to ½% of upper range limit*). Sensitive to pressure changes of ½" water. Here's accuracy and sensitivity never before thought possible in measuring process pressures—plus the convenience of suppressed ranges at high pressure levels.

THREE IMPORTANT ADVANTAGES:

1. Range spans of 20 and 40 psi available throughout range limits of 35 to 415 psia.

2. Volumetric type pressure system is extremely accurate, practically clog-proof, has corrosion-resistant 316 stainless steel diaphragm.

3. Temperature and barometric compensation for higher accuracy of measurement and control.

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IN HOME AND INDUSTRY

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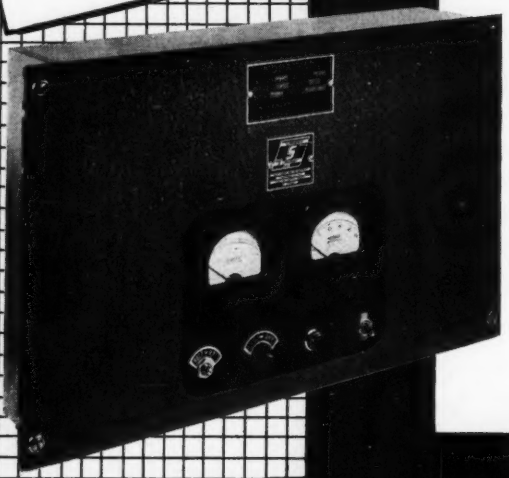
NOBATRONS

(DC VOLTAGE REGULATORS)



MODEL NO. E-6-15

DO YOU WANT the *advantages* of storage battery characteristics without the *disadvantages?* Then equip with Sorensen NOBATRONS! You get adjustable output voltage, stabilized against changing line AND LOAD conditions. You eliminate battery charging and maintenance, gas, acid hazard.

Like all Sorensen regulators, the NOBATRON is a painstakingly engineered combination of fine workmanship and top-quality components. That means accurate, trouble-free operation; long life!

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E-6-5	E-6-40
E-6-15	E-6-100

12-VOLT SERIES

E-12-5	E-12-30
E-12-15	E-12-50

28-VOLT SERIES

E-28-5	E-28-70
E-28-10	E-28-150
E-28-30	E-28-350

48-VOLT SERIES

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Model numbers indicate voltage and current; for example, E-6-5 indicates 6 VDC with 5 amp total capacity.

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Input voltage range	95-130 VAC; adapter transformers available for 230 VAC operation*
Output voltage range	Adjustable ± 10%
Regulation accuracy and load range	± 0.2% from 1/10 load to full load
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Input frequency range	50-60 cycles

*Some high current units require three-phase input

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For other regulation problems investigate Sorensen's line of AC Voltage Regulators, Voltage Reference Standards, DC Power Supplys.

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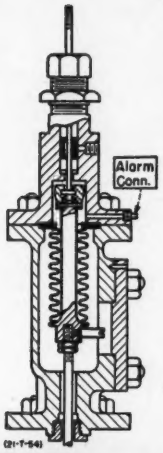

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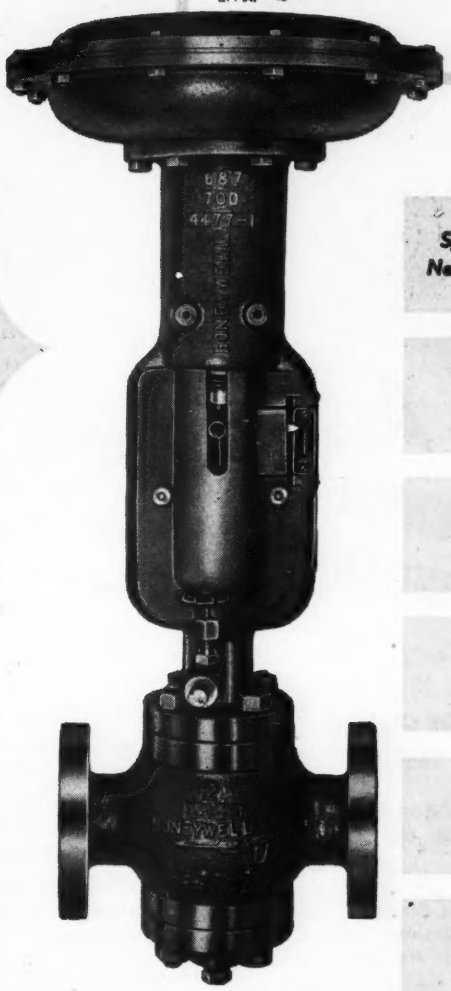
Packless Bellows Seal provides protection against fluid leakage or air infiltration. Special construction eliminates buckle or twist, assures positive seal between its housing and bonnet. Tap, in housing, permits alarm connection. Unit is easily replaced in field. Available in Monel for pressures up to 300 lbs. or in stainless steel to 600 lbs. In addition, conventional stuffing box affords added safety.



Specially Designed Neoprene Diaphragm

Duplex Upper Stem Guide

Safety Stem Lubricator

One-Piece Bonnet

Wide Variety of Discs

Reversibility in the Field

* Compare the Bellows Seal of this valve with that of any other wide band proportional type. Look at it closely . . . study it feature by feature.

Then check the other features of the valve . . . the Specially Designed Diaphragm, the Duplex Stem Guide, the One-Piece Bonnet, the Safety Stem Lubricator, the wide variety of discs, the easy reversibility in the field.

Your comparison will prove that the Honeywell Series 700 has *all* the features you look for in a fine valve.

It's available in a wide range of styles and sizes. For detailed information, write for a copy of Bulletin 700-2, or call in your local Honeywell engineer . . . he is as near as your phone.

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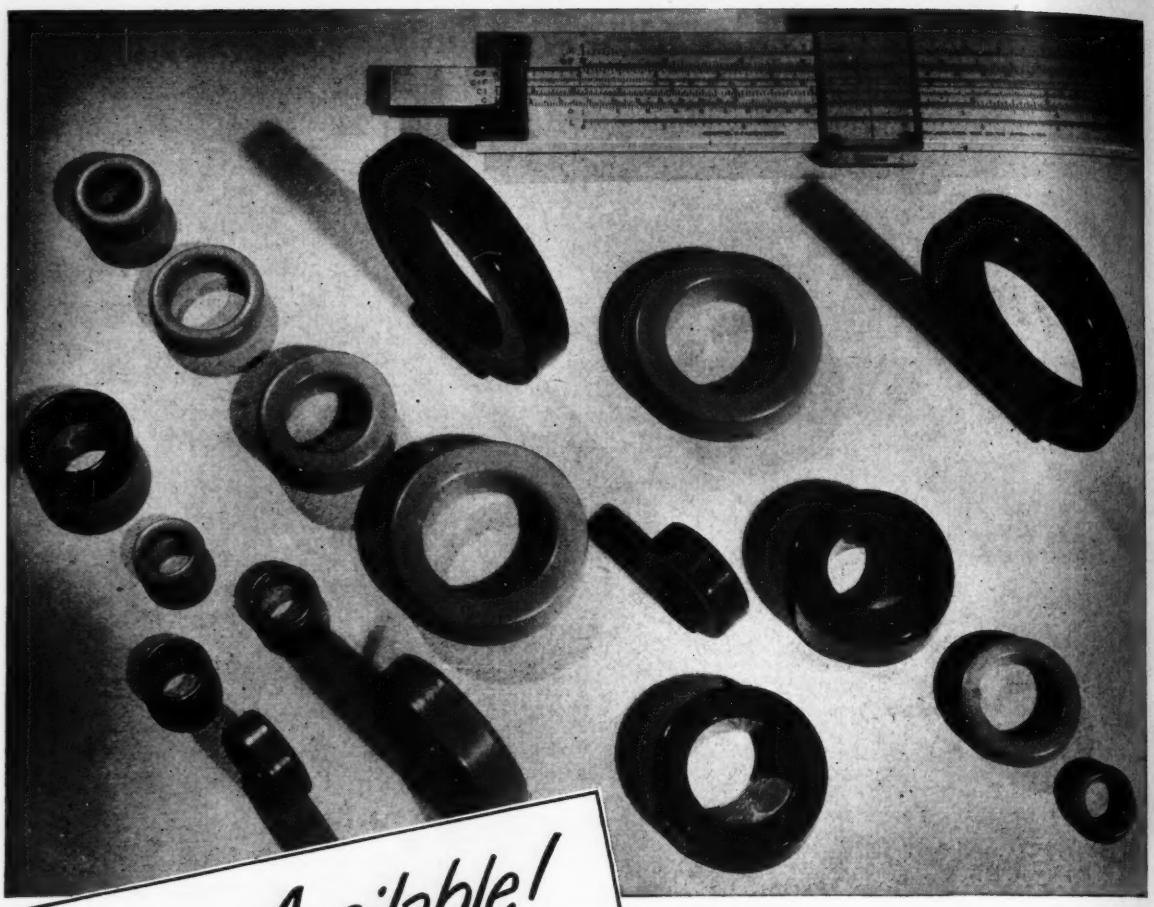

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W&D 2930

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The four sources of supply and service indicated above add another Foxboro *plus value* to the advantages of these unique process control valves. Each source is equipped to assemble Stabilflo Valves in a variety of sizes and materials to meet most specific needs . . . and staffed by expert application engineers and valve specialists.

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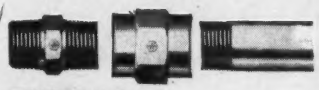

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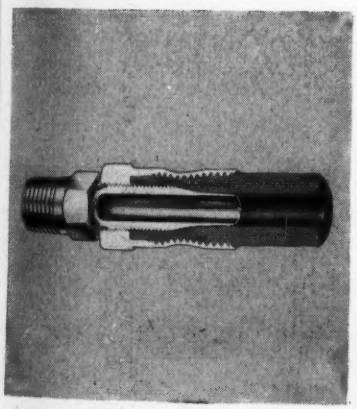

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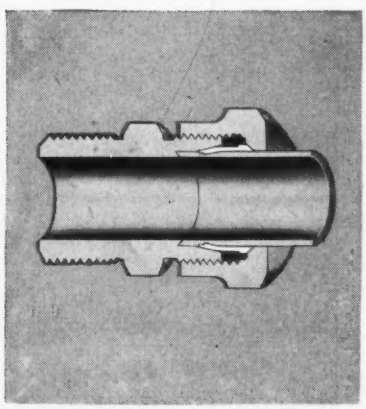

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INSTRUMENTS

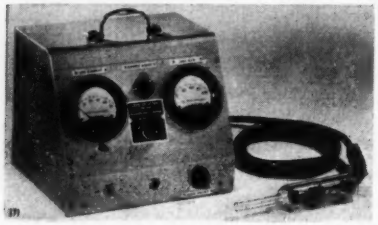
The Month's NEW INSTRUMENTS

In this department we report each month new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions.

FOR FURTHER INFORMATION USE THE POSTAGE-FREE ORDER CARD ON PAGE 485

Leak Detector

New "Model LD-01", leak detector is operated by sealing glass sensitive tube into system under test and then pumping down to a moderate vacuum. A jet of Freon or other halogen-containing gas is then directed against

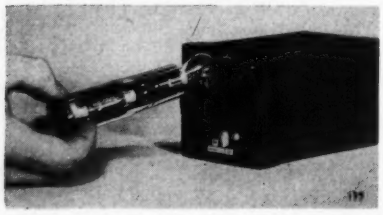


portions of system suspected of leaking. When jet strikes a leak there is a sudden deflection of indicator needle on instrument face, because gas entering system instantly increases ability of a hot platinum anode in sensitive tube to emit positive ions. Circuit employs three standard radio tubes and is housed in a cabinet 10.25 × 7.5 × 8 in. Sensitive tube is 5 in. long 1.31 in. diameter and has 3-in. tubulation, 0.44-in. outside diameter. — *Distillation Products Industries, Rochester, N. Y.*

Mention No. 401 when filling out card.

Smoke Detector for Aircraft

New visual smoke detector for aircraft draws air from cargo compartments through small-bore tubing to detector mounted on instrument panel. Face of detector contains two viewing windows looking into "black chambers" through which an invisible beam of



light passes. If air sample contains smoke, it will reflect light beam and show as a bright streak. To check light bulb, moving a small lever opens a shutter and permits light from bulb to illuminate a small amber button. A flasher unit causes light beam to flash on and off calling attention to smoke signal. Flash can be changed to steady signal for visual analysis. Complete unit holding flasher and bulb can be unscrewed by hand. Case of detector unit fits into a standard opening on instrument panel. Unit measures 3.25 in. sq. x 6.5 in.; weighs 1.25 lb.—*Walter Kidde & Co., Inc., 40 East 34th St., New York 16, N. Y.*

Mention No. 402 when filling out card.

Gage Blocks

New "AA" grade gage blocks are accurate to 0.000002 in.; are available in 37 and 83 piece sets. They meet NBS specifications with regard to size,

flatness, parallelism, surface finish, hardness and stability. Accessories such as gage holders, scribers, and dial indicators, are also available.—*DoALL Co., Des Plaines, Ill.*

Mention No. 403 when filling out card.

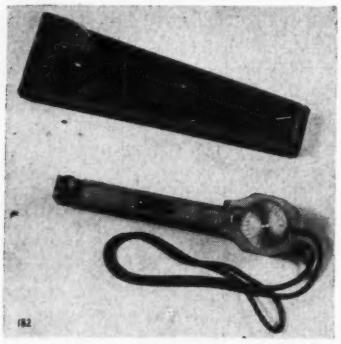
Two-pen Electronic Recorder

New two-pen electronic recorder has been applied to recording radioactivity and rock strata resistance in drilling operations. Instrument may be used to record two related variables, as in spectrographic analysis, meteorology, and film-coating processes.—*Brown Instruments Div., Minneapolis-Honeywell Regulator Co., 4482 Wayne Ave., Philadelphia, Penna.*

Mention No. 404 when filling out card.

Optical Rangefinder

New field rangefinder measures distances from 8 to 100 ft.; over-all accuracy is within 2 percent. Instrument



operates by superimposing images viewed through lenses 6 in. apart. Object distance is read directly on dial.—*Meyer-Opticraft, Inc., 39 W. 60th St., New York 23, N. Y.*

Mention No. 405 when filling out card.

Direct-reading Spectrometer

New "Quantometer" for analysis of metals is applicable to a wide variety including stainless steel and similar materials. Based on spectroscopic principles, instrument provides record-

analyses of samples, element by element within two min. Mechanism can produce multiple copies of records when desired. A single unit can measure 25 elements, up to 20 simultaneously. Results are comparable to chemical analysis.—*Applied Research Laboratories, 4336 San Fernando Rd., Glendale 4, Calif.*

Mention No. 406 when filling out card.

Multi-point Strip-chart Recorder

New "Capacilog" multi-point recorder provides up to six records. Input for deflection-type system can be provided

by thermocouples, radiation detectors, etc. Instrument is accurate to 0.25 percent of full scale.—*Wheelco Instruments Co., 847 W. Harrison St., Chicago 7, Ill.*

Mention No. 407 when filling out card.

Optical Gaging Projector

New "Model 3" contour projector allows 8 in. between lens and object for all magnifications up to 100×. Projector body, work table, and lamp house

ALNOR THERMO-ANEMOMETER Here's a compact, direct-reading instrument that fills a long-felt need—the accurate measurement of low air velocities. With the Alnor Thermo-Anemometer you can accurately read velocities as low as 5 f.p.m. It can be used between 20°F. and 150°F. without impairing its accuracy. Fine craftsmanship, high-quality materials, exact calibration, and exhaustive tests combine to assure you accurate operation on a wide variety of applications.

ALNOR ELECTRONIC TEMPERATURE CONTROLLER . . . is a simplified form of controller designed to indicate and regulate automatically the heat of any industrial heating device. There are no moving mechanical parts to wear or cause trouble. Control sensitivity is such that pointer movement of 0.3% will activate the power relay. Available with a wide variety of thermocouples and in scale range from 0-500 to 0-3000°F.

ALNOR DEW POINT INDICATOR . . . for simple, rapid dew point reading of any gas. Indication takes place in an enclosed observation chamber under accurately controlled conditions. Dew or fog suspended in air—not on mirrored surface—makes it easy for two or more observers to get same accurate results. The Alnor Dewpointer is a complete, self-contained unit—no external coolant or other apparatus is required. Available for dew points from −80° F. to room temperature.

ALNOR TYPE 2300 SURFACE PYROMETER . . . sets a new high in precision measurement of low surface temperatures. Special design, from Alnico magnet to the finest, quick reacting thermocouple, assures unfailing accuracy . . . speed and dependability. This is a self-contained, sturdy unit—easily carried and used anywhere on a wide variety of applications. Direct reading, six-inch mirrored scale is easily read . . . quickly understood. The instrument is available in 5 Fahrenheit scale ranges with a span as small as only 150°.

for precise measurement of temperature, air velocity and dew point!

If your measurement problems involve any of these, choose a precision instrument from the Alnor line. Unexcelled for unfailing accuracy, Alnor instruments have proved their superiority in a broad range of laboratory, production-line and field applications. The units shown are but a few from a full line of rugged precision instruments that have many unique patented features that mean greater accuracy . . . a more practical, trouble-free solution to your measurement problems.

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ALL
valves leak!

But here's a rapid and accurate answer to where and how much.

THE SAMPLING PROBE shown here is part of the Consolidated Model 24-101A Leak Detector. Its application is by no means confined to valve assemblies. Industrial or laboratory vacuum equipment, high pressure cylinders, compressor units moving on an assembly line, glass-to-metal seals in electronic equipment, valves, welded and soldered joints—these are but a few of the many pieces of equipment and systems which can be tested.

The Model 24-101A Leak Detector is a simplified, portable mass spectrometer sensitive to minute traces of helium. For each application there is a particular setup which gives optimum results. However, the basic methods are few, are easy to understand, and are easy to put into practice. It avoids the use of liquids—which can clog leaks—or any corrosive, toxic, or explosive materials for testing.

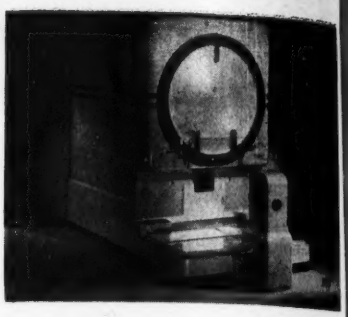
This instrument tests either evacuated or pressurized equipment. It is employed to show the existence or absence of any leak, to determine the rate of leakage, or to find the exact location of a leak. Its versatility is second in importance only to its remarkable sensitivity. It will detect leaks so small that it would require 31 years for a thimbleful of gas to escape.

Furnished as a complete, compact unit mounted on rubber casters. Standard equipment includes both visual and audible indicators.

For complete information on construction, operating principle and application, request your copy of this profusely illustrated, 16-page bulletin CEC-1801-X21. Please use your company letterhead. No obligation, of course.

Consolidated **LEAK DETECTOR**

CONSOLIDATED ENGINEERING
Corporation
Analytical Instruments for Science and Industry
300 N. Sierra Madre Villa Pasadena 8, California



can be separated for attachment to large fixtures used in optical gaging of very large equipment. Unit has accessory by which light can be sent out of same lens that picks up image so that surfaces and deep recesses which cannot be shadow projected may be examined. Instrument is designed for production line inspection, maker states.—*Eastman Kodak Co., Rochester 4, N. Y.*

Mention No. 408 when filling out card.

Portable Carbon Dioxide Indicator

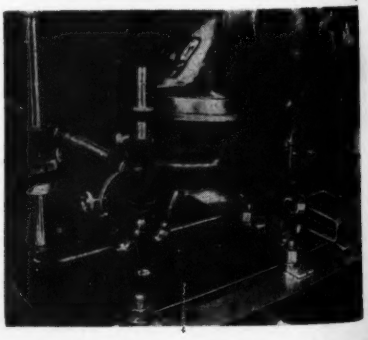
New carbon dioxide indicator is fabricated from transparent lucite bar stock. Unit has open-faced dial and is fur-

nished with circular efficiency slide rule. It is available in heavy metal case with provision for stack thermometer, draft gage and smoke tester.—*F. W. Dwyer Mfg. Co.*, 317 *S. Western Ave., Chicago 12, Ill.*

Mention No. 409 when filling out card.

Milling Machine Duplicating Attachment

New duplicating attachment for knee-type milling machines uses an optical follower system which reproduces co-



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Records with

HAGAN

RING BALANCE METERS

In every flow distribution system, it is important that the record of total flow balance with the sum of individual flows, so that costs can be allocated properly.

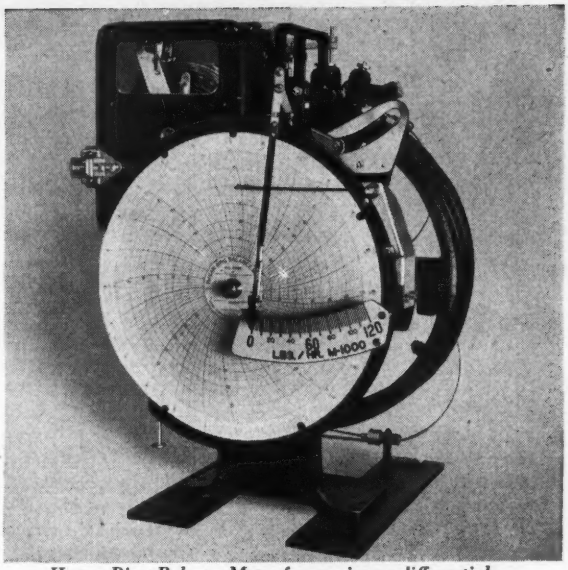
With Hagan Ring Balance Meters, the records and totalized flows are accurate over the full meter range, and distribution costs can be made on the correct basis.

Hagan Ring Balance Meters are available in single or dual models, with or without automatic pressure and temperature compensation, and for full scale differentials up to 420″ of water.

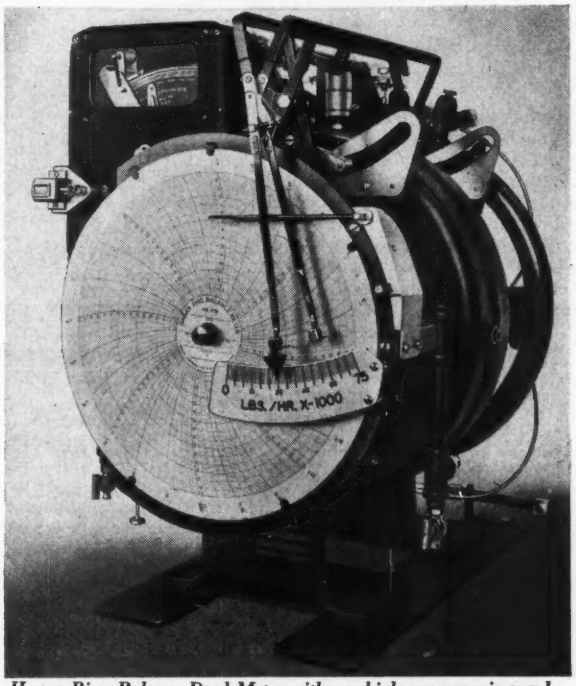
For more information about Hagan Ring Balance Meters, write to Hagan Corporation, Hagan Building, Pittsburgh 30, Pennsylvania.

HAGAN CORPORATION

RING BALANCE FLOW AND PRESSURE INSTRUMENTS
THRUSTORQ FORCE MEASURING DEVICES
BOILER COMBUSTION CONTROL SYSTEMS
METALLURGICAL FURNACE CONTROL SYSTEMS



Hagan Ring Balance Meter for maximum differential of 420″ water column.



Hagan Ring Balance Dual Meter with one high pressure ring and one low pressure ring; integrator; and strip type indicating arc.

Hagan Corporation
Hagan Building
Pittsburgh 30, Pennsylvania

Please send me further information on Hagan Ring Balance Meters. I am particularly interested in_____

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I-4

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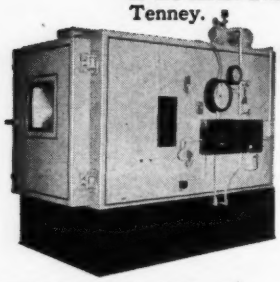
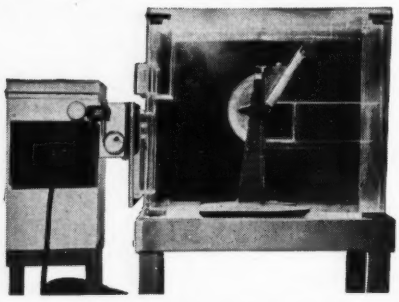


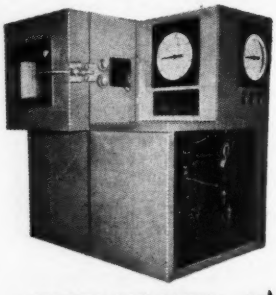
TENNEYZPHERE ALTITUDE CHAMBERS

Designed to withstand atmospheric pressure and to simulate global conditions of pressures, temperatures and humidities. Altitudes from sea level to approx. 75,000 ft. Temperature range from plus 200°F to minus 100°F. Also simulates desired relative humidity.

TENNEY SERVO UNIT

Portable air conditioning unit which may easily be attached to various types of laboratory enclosures—impact machines; tension machines; torsion testers; cold boxes and similar equipment. Through its use, articles undergoing testing, aging or weathering can be subjected to wide variations of humidity, heat and cold.



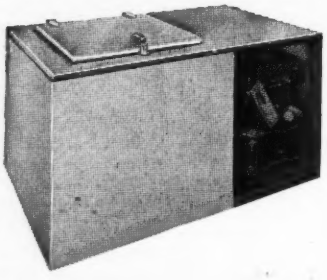


TENNEY TEMPERATURE AND HUMIDITY CHAMBER

Designed for positive control of temperature, humidity and air circulation. Permits the accurate checking of physical quality, fragility, tension and other factors.

TENNEY SUB-ARCTIC INDUSTRIAL CABINETS

Designed for low-temperature testing of metals, radios, instruments, plastics, liquids, chemicals and pharmaceuticals. Temperature ranges of −40°F, −60°F, −95°F and −150°F are standard for each size.



For further information on these and other Tenney test equipment, write to Tenney Engineering, Inc., Dept. B, 26 Avenue B, Newark 5, New Jersey.

Tenney

Engineers and Manufacturers of Automatic Temperature, Humidity and Pressure Control Equipment

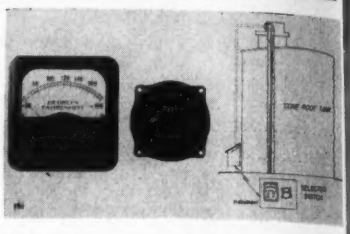
7854

ordinate location to 0.0002 in. Instrument has a 32× microscope with cross-hairs for following templates laid out on flat plates.—*Boeckeler Instrument Co., 29 E. Rillito St., Tuscon, Ariz.*

Mention No. 410 when filling out card.

Averaging Resistance Thermometer

New "Model 918" averaging resistance thermometer is designed for use in oil storage tanks. Instrument consists of flexible resistance-bulb assem-

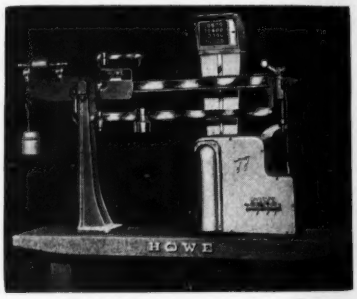


bly, indicator, and oil-level selector switch. Indicator is available in any scale with a span not less than 100 deg. F.; accuracy is 0.5 percent of scale range. Assembly operates on 6 v. d.c.—*Weston Electrical Instrument Corp., 641 Frelinghuysen Ave., Newark 5, N. J.*

Mention No. 411 when filling out card.

Direct-reading Chart for Beam Scales

New "77 Weightograph" is an accessory for beam scales; unit is attached to beam shelf and connected to beam by a rod. Upward pull of rod swings



instrument chart in an arc between a stationary light and magnifying lens. Magnified reading of chart figures are reflected by mirrors to screen of periscope for reading. Beam movements are damped by an oil dashpot. Reading line length is 180 in.—*Howe Scale Co., Rutland, Vt.*

Mention No. 412 when filling out card.

Weather-controlled Steam Valve

New "Type W" heating control valve for steam heating systems responds to outdoor temperature; position of valve is determined by outdoor bulb and steam pressure in system. Orifice plates are installed in radiator or convector valves to equalize distribution. Control valve is operated by electrohydraulic motor; control panel has a 4-position selector switch and a time switch for night shut-

In Tube Fittings, Valves and Tubing Tools the IMPERIAL LINE is the COMPLETE LINE

FITTINGS

Finer because they're FORGED!

For Connecting Copper, Brass, Aluminum Thin-Wall Steel and Flexible Tubing.

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Simple, efficient, easy to assemble.

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For low, medium, high pressure work. Gives repeated tight reconnection.

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Available in Brass or Aluminum. Easier to assemble. Withstands vibration.

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Has flexible synthetic sleeve. Withstands major vibration, minor tube movement.

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Similar to flared tube fitting except seat for flare is inside body.

FLEXIBLE HOSE and FITTINGS

For making up flexible liquid, air and vacuum lines.

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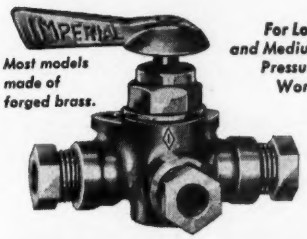
Most shapes now forged for greater strength.

SHAPES and SIZES Elbows, tees, crosses, straight fittings. Std. sizes ⅛" to ¾" O.D. tubing. Pipe thread ends ⅛" to ½" P.T.

VALVES



Most models made of forged brass.

For Low and Medium Pressure Work.

2-WAY HI-DUTY VALVES

An extra sturdy valve for liquids and gases. Note solid bottom.

3-WAY AND 4-WAY HI-DUTY

Outstanding shut-off or distributing valve for liquids, gases.

2-WAY SHUT-OFF VALVES

General purpose plug valves for a host of applications.

3-WAY SHUT-OFF VALVES

For liquid and air lines or wherever two fuel tanks are used.

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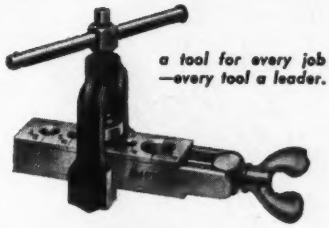
Popular low cost valves. Compression, flare and pipe thread connections.

DRAIN COCKS

Plug and needle types. Variety of styles. Positive shut-off, smooth operation.

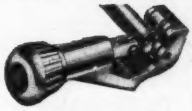
VALVE SIZES ⅛" to ½" O.D., ⅛" to ¾" P.T.

TUBE WORKING TOOLS



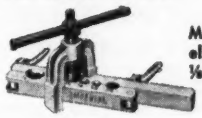
a tool for every job —every tool a leader.

TUBE CUTTERS



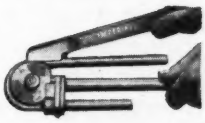
Various sizes. Make clean right angle cuts on tubing ⅛" to 2¼" O.D.

FLARING TOOLS



Many excellent models to flare tubing ¼" to 1" O.D.

TUBE BENDERS



Hand benders of open-side, heavy-duty and spring types. Sizes ⅛" to ¾" O.D.

OTHER TUBING TOOLS

in the complete Imperial line include reamers, swedging, pinch-off and refacing tools and soldering torches.

See Your Industrial Supply House

Illustrated here are only a few representative products in the complete Imperial Line which is described in Catalog No. 350. Ask for your copy.

THE IMPERIAL BRASS MFG. CO., 1204 W. Harrison St., Chicago 7, Ill.

IMPERIAL PIONEERS IN TUBE FITTINGS AND TUBE WORKING TOOLS

No. 50—Product of Barber-Colman Company Rockford, Illinois

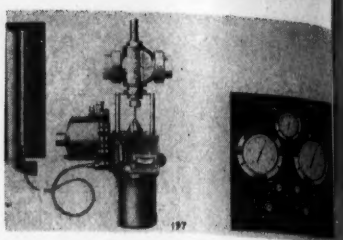
The precision response of this Chace Thermostatic Bimetal blade "shaves" room temperature differentials to 1°F! The thermostat is Barber-Colman's Microtherm, used with their motor-operated proportioning valves or damper control motors; it contains a solenoid which positions these control units in accordance with heat demand.

Low room temperature moves the contact-carrying bimetal toward contact "A". This closed circuit causes the motor to rotate the unit toward "full open" position and moves a rheostat arm, positioned from the final drive shaft, toward its maximum voltage. The rheostat energizes the solenoid "B", which pulls the blade away from the top contact before rising temperature causes bending of the bimetal. The fully energized solenoid pulls the blade to the lower contact "C", reversing rotation of the unit toward closed position. The rheostat then reduces voltage to the solenoid, thus reducing its pull on the bimetal blade, which can now move upward as temperature lowers, beginning another cycle.

Chace furnishes this element completely fabricated, ready for installation in the thermostat. Chace Thermostatic Bimetal is also available in strips, coils, random long lengths and welded or brazed sub-assemblies. Ask the Chace Application Engineer which of these forms will best fulfill *your* thermostatic bimetal requirements.

IT BENDS WITH THE HEAT

W. M. CHACE CO.
Thermostatic Bimetal
1609 BEARD AVE., DETROIT 9, MICH.



down and morning pickup.—*Sarcotherm Controls, Inc., Empire State Bldg., New York* 1, *N. Y.*

Mention No. 413 when filling out card.

Black-granite Surface Plate

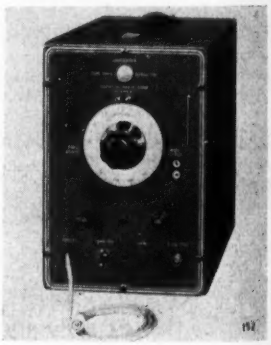
New "Micro-Flat" surface plate is made of black granite and surface is claimed to be harder than tool steel.

It is non-magnetic non-deflecting nonglaring and requires no oiling. Unit is available in sizes from 9 × 12 in. to 54 × 108 in.—*Collins Granite Surface Plate Co.*, 1331 *Santa Fe Ave., Los Angeles* 21, *Calif.*

Mention No. 414 when filling out card.

Frequency Converter Accessory

New "Type 207-A" frequency converter is designed for use with maker's Type 202-B FM signal generator, to provide coverage from 0.1 to 216 Mc. Dial of new unit is calibrated in 5 kc.

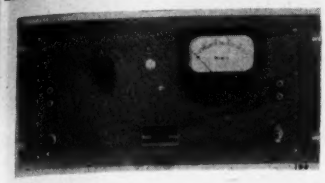


steps from −300 to 300 kc. RF output at unity gain jack is variable from 0.1 microvolt to 0.1 volt; gain is constant within 1 db over entire frequency range. An uncalibrated high voltage is available at a front panel pin-jack. Supply voltage is internally regulated. —*Boonton Radio Corp., Boonton, N. J.*

Mention No. 415 when filling out card.

Linear to Logarithmic Converter

New "Model 124" linear to logarithmic converter is used with standard direct-writing oscillograph; maximum



pen speed is 5000 db per sec. but other speeds down to 600 db per sec. available. Unit includes linear rectifier and d-c. amplifier to drive oscillograph. Instrument has 50 db range.—*Audio Instrument Co., 133 W. 14th St., New York 11, N. Y.*

Mention No. 416 when filling out card.

Volt-ohm-milliammeter

New "Model 458A" volt-ohm-milliammeter indicator is rated 1000 ohms per v. Unit has voltage ranges from 2.5 to 5000; milliamp. ranges from 1

to 100, both alternating and direct. Instrument measures to 10 amp. a.c. and d.c. and has resistance ranges to 2 megohms full scale.—*Chicago Industrial Instrument Co., Chicago 10, Ill.*

Mention No. 417 when filling out card.

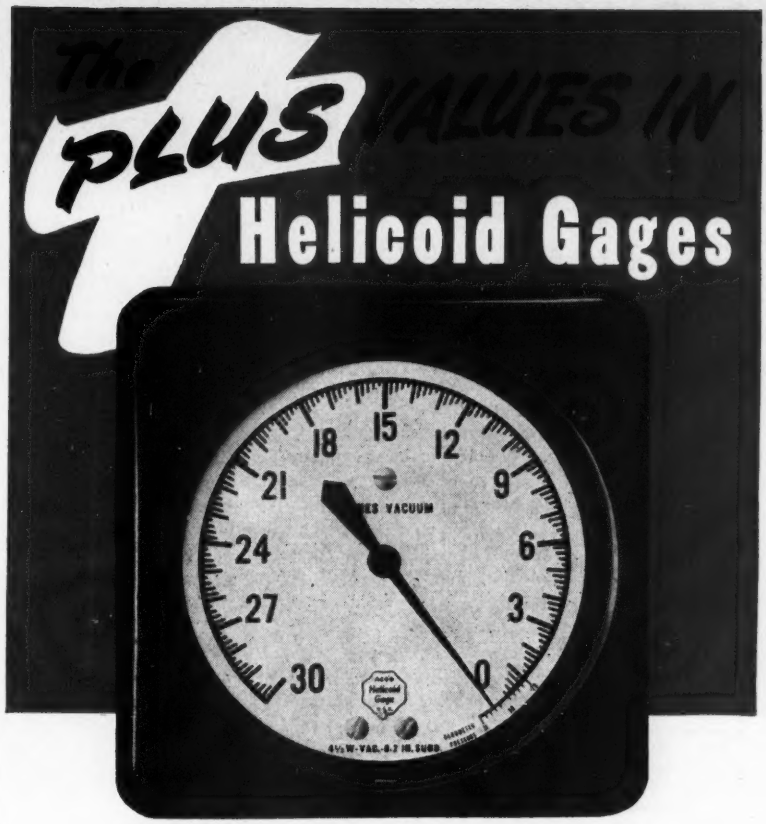
Portable Moisture Testers

New "Models A and H" portable moisture testers operate on electrical conductivity principle. A weighed sample is compressed to a known volume, its volume resistance is read on a hand-cranked ohmmeter, and its temperature read on a built-in thermometer. Moisture content is found by aligning these readings on dials. Model A covers from 10 to 22 percent moisture, Model H from 8.5 to 40 percent. — *Burrows Equipment Co., 1316 Sherman Ave., Evanston, Ill.*

Mention No. 418 when filling out card.

Ultra-sensitive D-c. Amplifier

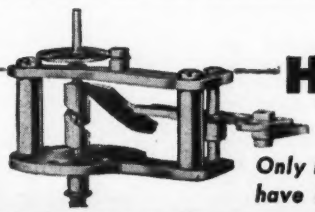
New "Models 10 and 10-A" d-c. amplifiers use two synchronously-driven breakers which convert d-c. input to a.c. for amplification and back to d.c. for output. Response in Model 10 is flat to 1 cps.; in Model-10A to 15 cps. Unit is available for inputs of 0 to 0.5 megohm. Output is linear to 4 v. with



This Vacuum Gage is an example of the extra value at no extra cost in all HELICOID GAGES.

Note:

1. Dial in inches of mercury vacuum, reading counter-clockwise, to denote negative pressure and prevent confusion with a 30 lb. pressure gage.
2. Even if subjected to 30 lb. pressure, no harm will result because the Helicoid cam releases from the roller on the pressure side. Other vacuum gages are damaged by pressure.
3. Subdivisions in graduated steps of 0.2 inches for ease in reading scale.
4. Hairline Pointer adjuster to correct zero setting for changes in barometric pressure.
5. Guaranteed accuracy to within 0.15".
6. The new square flush case. Another Helicoid "*first.*"



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Only Helicoid Pressure Gages have the Helicoid Movement

TRADE MARK

HELICOID GAGE DIVISION
AMERICAN CHAIN & CABLE COMPANY, INC.
Bridgeport 2, Connecticut

NEW ONE-PACKAGE CONTROL SYSTEM

for DIFFERENTIAL TRANSFORMERS or STRAIN GAGES at the Flip of a Switch

DYNA-MYKE

The Dyna-Myke Model 129-B is a precision, high speed, dynamic micrometer using linear differential transformers as the sensing element. It measures and provides for recording such phenomena as force, torque, strain, vibration, acceleration, temperature, pressure, thickness, surface finish, etc., with a linear frequency response of DC to 1000 cps. Direct displacements are measured in five ranges from ±.1 inch to ±10 micro inches. On standard magnetic recorders a sensitivity of 1 micro inch per millimeter is available. A toggle switch converts the Dyna-Myke to a high frequency, high sensitivity strain gage indicator. The output is used to drive any type of magnetic, null balance or galvanometer recorder—or the DC or modulated carrier may be viewed on an Oscilloscope. Selsyn motors may be driven for remote indication or control. Request Technical Bulletin 129-B for full details.

DYNA-METER

The Dyna-Meter Model 144, when used with the Dyna-Myke, indicates by neon lights the peak amplitude of transients as fast as 1 millisecond. This indication may be instantaneous or a memory feature may be used to maintain the reading until reset. Built-in power relays provide on-or-off control to any plus or minus limits established by the Dyna-Myke. The combination of the Dyna-Myke and the Dyna-Meter offers many applications to industrial processes resulting in the elimination of scrap *at the source*. Uses in connection with machine tool operations are particularly impressive. Request Dyna-Meter Technical Bulletin 144.

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500-ohm load, to 14 v. with infinite impedance meter. Signal-to-noise ratio is within a factor of 2 of Johnson-noise limit. Zero stability exceeds 0.005 microvolt and gain stability is better than 0.3 percent over an 8-hr. period. Overall dimensions 22 x 15 x 10.5 in.—*Liston-Folb Instrument Co., Inc., Stanford, Conn.*

Mention No. 419 when filling out card.

Die Temperature Controller

New temperature controller for aircraft dimpling dies uses maker's "Simplytrol" pyrometers. Two double-

contact instruments are used, one for each section of die. Temperature range is 350 to 750 F.—*Assembly Products, Inc., Chagrin Falls, Ohio.*

Mention No. 420 when filling out card.

Low-frequency Oscillator

New "Model 410-A" low-frequency oscillator provides sine and square wave outputs from 0.02 to 20,000 cps. Six frequency bands are provided, each covering a full decade. A single 11-in.

illuminated direct-reading logarithmic scale is used on all bands. Instrument features low distortion and hum level, constant output impedance, excellent frequency stability and amplitude constancy over entire frequency range, maker states.—*Krohn-Hite Instrument Co., 580 Massachusetts Ave., Cambridge 39, Mass.*

Mention No. 421 when filling out card.

Indicator for Resistance Thermometers

New "Speed Bridge" is an electrical indicator covering temperature range from −200 to 1600 C. or equivalent F. with two types of resistance thermometers. Ranges are changed by exchanging two plugs containing bridge arms.

Can You Use A Metal That RESISTS OXIDATION at 3,000°F

★ *Coated molybdenum strip undergoing laboratory life test. Life of 2500 hours at 2000°F is not uncommon.*

Fansteel Siliconized Molybdenum is an entirely new material for high temperature service up to 3000°F. To the strength and workability of pure molybdenum is added an impervious coating which resists both oxidizing and reducing atmospheres, providing a strong, electrically conductive material, comparatively abundant, reasonable in cost.

The bond between the coating and base metal is integral; the coating does not flake, peel or spall. It is highly resistant to thermal shock.

Available forms include fabricated parts, bar, rod, wire, seamless tubing, special shapes. Fansteel Metallurgical Corporation, North Chicago, Ill., U.S.A.

Ask for Bulletins:

- ☐ Fansteel Siliconized Molybdenum
- ☐ Fansteel 77 (high density) Metal
- ☐ Fansteel Tungsten and Molybdenum
- ☐ Fansteel Tantalum

12502-A

Fansteel

SPECIAL PRODUCTS *In Controlled Metallurgy*

Three ranges are available by operating two toggle switches. Accuracy is 0.1 deg. over entire scale. Over-all dimensions 12 × 7 × 8 in.; instrument operates 115-v. 60-cps. line.—*Weiller Instrument Corp., 95 Broad St., New York 4, N. Y.*

Mention No. 422 when filling out card.

Wide-range Test Oscillator

New "Model 3432" test oscillator has five fundamental ranges from 165 kc. to 40 Mc. and two harmonic ranges from 36 to 120 Mc. RF selector provides high and low outputs with a fine-control attenuator. Circuit selector provides for internally modulated signal, variable 0 to 100 percent at 400 cps. Vari-

able amplitude of external modulation from 40 to 15000 cps., unmodulated signal, or variable audio output 0 to 10 v. at 400 cps. All RF and audio circuits are shielded with copper-plated steel. Seven illuminated scales cover 330 deg. rotation. Over-all dimensions 15.38 x 11 x 6.25 in.; weight 14.5 lb. Instrument operates on 115-v. 60-cps. line.—*Triplett Electrical Instrument Co., Bluffton, Ohio.*

Mention No. 423 when filling out card.

Automatic Resistance Comparator

New "Type PR-5" resistance comparator checks resistors against a standard and indicates percent off standard.

Accuracy is 1 percent in range from 100 ohms to 100 megohms. Instrument operates from 115-v. 60-cps. line. Indicator has three ranges from 5 to 100 percent off standard. Over-all dimensions 18 × 12 × 12 in.; weight 32 lb.—*Clippard Instrument Laboratory, Inc., Cincinnati, Ohio.*

Mention No. 424 when filling out card.

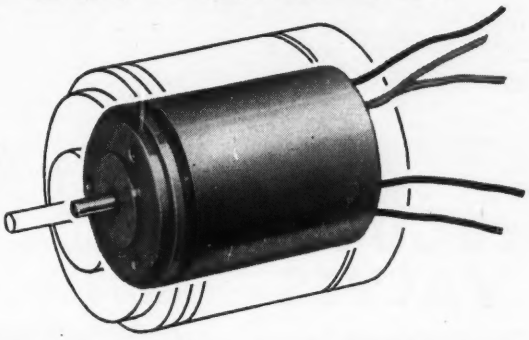
Half-octave Filter

New "BP-1" filter has separate high- and low-pass filters, each having 17 cut-off frequencies from 37.5 cps. to 13.6 kc. in 0.5-octave steps centered on 1000 cps. Selection of cut-off frequencies is made by push-button switches.

ECLIPSE-PIONEER

Announces the New Line of

PYGMY SYNCHROS



Size of pygmy as compared to AY-200 series outline

Eclipse-Pioneer has added a tiny new member to its great family of famous Autosyn* synchros. It's the new AY-500 series, a precision-built pygmy weighing only 1¾ oz. while scaling only 1.278″ long and .937″ in diameter (the same diameter, incidentally, as a twenty-five cent piece). Its accuracy and dependability are assured, thanks to Eclipse-Pioneer's 17 years of experience and leadership in the development of high precision synchros for aircraft, marine and industrial applications. For more detailed information on the AY-500 and other E-P Autosyns, such as the remarkably accurate AY-200 series (guaranteed accuracy to within 15 minutes on all production units), please write direct to Eclipse-Pioneer, Teterboro, N. J.

*REG. TRADE MARK BENDIX AVIATION CORPORATION

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REG. U.S. PAT. OFF.

Typical Performance Characteristics

	One AY-201-3 Driving		One AY-500-3 Driving
	One AY-500-3 Control Transformer	Two AY-500-3 Control Transformer	One AY-500-3 Control Transformer
INPUT			
Voltage	26-volts, single-phase	26-volts, single-phase	26-volts, single-phase
Frequency	400 cycles	400 cycles	400 cycles
Current	88 milliamperes	110 milliamperes	55 milliamperes
Power	0.8 watts	1.2 watts	0.9 watts
Impedance	105+j280 ohms	100+j220 ohms	290+j370 ohms
OUTPUT			
Voltage Max. (rotor output)	17.9 volts	16.2 volts	14.1 volts
Voltage at null	40 millivolts	40 millivolts	40 millivolts
Sensitivity	310 millivolts/degree	280 millivolts/degree	245 millivolts/degree
Voltage phase shift	23 degrees	26 degrees	44 degrees
System accuracy (max. possible spread)	0.6 degrees	0.6 degrees	0.75 degrees

Other E-P precision components for servo mechanism and computing equipment:
Servo motors and systems • rate generators • gyros • stabilization equipment • turbine power supplies • remote indicating-transmitting systems and special purpose electron tubes.

For detailed information, write to Dept. A

ECLIPSE-PIONEER DIVISION of
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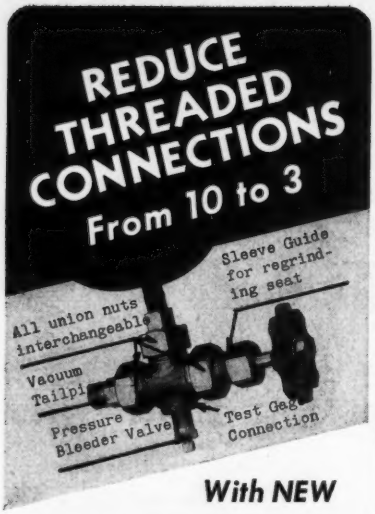

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Threaded connections are reduced from 10 to 3, for these valves combine unions, nipples, reducers, elbows, tees, valve, and drain valve in one space saving unit. One valve replaces the multiple set-up of valves and connections formerly used.

Nine different styles . . . with or without union outlet, as well as offset and jacketed valves.

Features available include safety shut-off; double-seating stem for repacking under pressure; regular or quick-closing stem and lever; regrindable and renewable seats; pressure bleeder valve and test gage connection; outside screw and yoke when desired; throttling stem when desired.

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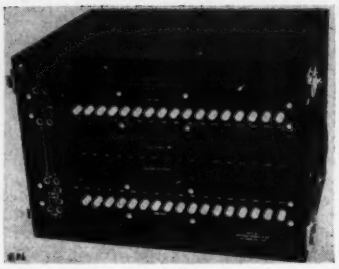
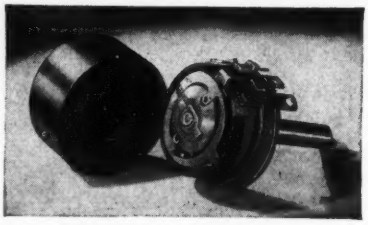


Frequency tolerance is 2 cps. or 2 percent. High- and low-pass units can be used separately. Attenuation outside pass band is 20 db for 0.25 octave and 40 db for 0.5 octave beyond 3-db point. Sealed high Q toroids and low dissipation capacitors are used in passive network. Over-all dimensions 19 × 13 × 13 in.; weight 70 lbs.—*Gertsch Products, 11846-48 Mississippi Ave., Los Angeles 25, Calif.*

Mention No. 425 when filling out card.

Precision Potential Divider

New potential divider has a tapered winding held to 1.5 percent linearity.



Unit is treated to meet fungus and corrosive conditions; body is molded in low-loss bakelite.—*Clarostat Mfg. Co., Inc., Dover, N. H.*

Mention No. 426 when filling out card.

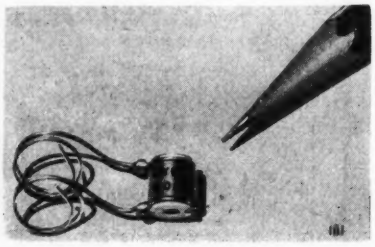
Platinum Resistance Thermometer

New platinum thermometer for high temperatures consists of platinum wire embedded in a ceramic matrix. Precision measurements can be made to 1400 C., and thermometer remains operative to 1600 C. Unit is mounted in a stainless steel tube for temperatures to 1000 C.; for higher temperatures it comes in a variety of ceramic tubes. Ice point resistance is 10 ohms.—*Weiller Instrument Corp., 95 Broad St., New York 4, N. Y.*

Mention No. 427 when filling out card.

Precision Resistors

New "Series E" precision resistors are non-inductively wound on ceramic bobbins using Evanohm or Manganin



PRINCO'S NEW A.S.T.M. LABORATORY THERMOMETER SETS

Cat. #0260 C
0260 F

● Nine certified extreme precision laboratory thermometers (ASTM Spec.) cover the interval between −38° C and +405° C, (−36° F to +760° F) Mercury-in-glass with finely divided scales and plush lined carrying case. These new thermometers are offered by PRINCO as part of the complete listing of ASTM spec. thermometers. Special folder issued on request.

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● These "PRECISION SPECIAL" Thermometer Sets have long been used as a laboratory standard. Six thermometers in case cover interval between . . .
−60° C or −38° C and +360° C
(−76° or −36° to +680° F).
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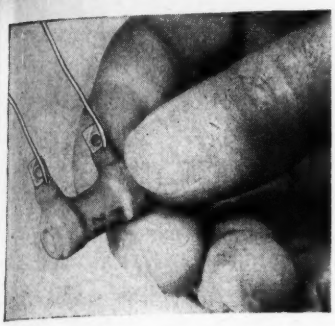
wire. Standard tolerance is 1 percent. Ratings from 0.25 to 1 watt available with wire leads or lugs. Units can be tropicalized.—*Hycor Co.*, 11423 *Vanowen St., N. Hollywood, Calif.*

Mention No. 428 when filling out card.

Wire-wound Resistors

New resistance values available for maker's "PR 5 F" resistors are 8000, 8500, 9000, and 10,000 ohms. Units are

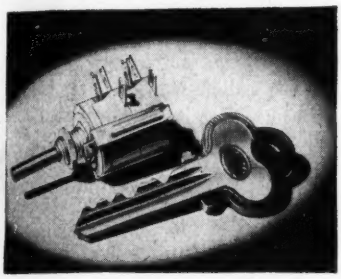


5-watt wire-round resistors with inorganic cement coating. 9000-ohm value has been added to 10-watt series.—*Clarostat Mfg. Co., Dover, N. H.*

Mention No. 429 when filling out card.

Sub-miniature Volume Controls

New "Series 48" composition-element sub-miniature controls are housed in yellow low-loss bakelite case 0.63 in. diameter by 0.38 in. deep. Two units

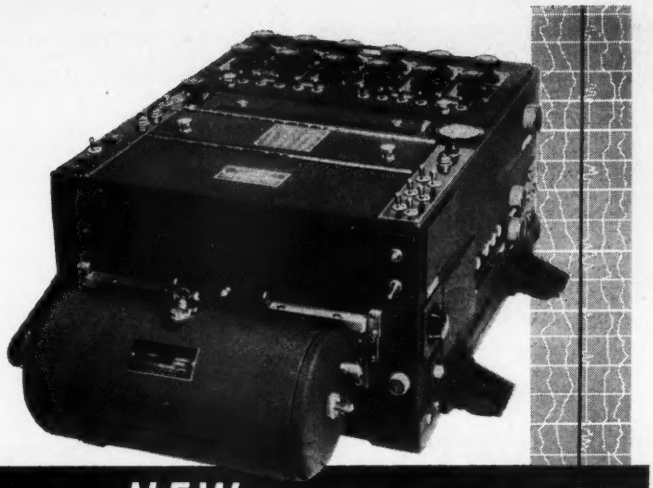


are shown held by metal straps for dual-control combination. Resistance values available to 3 megohms linear and in tapers to 1 megohm.—*Clarostat Mfg. Co., Inc., Dover, N. H.*

Mention No. 430 when filling out card.

Electronic Standard Cell

New electronic standard cell provides d-c. reference voltage stable to 0.25 percent; ripple on low-current models is less than 0.01 percent. Standard units provide 1.00, 10.00, 100.00 v. and elec-



the *NEW* S-8 Oscillograph

Here, in a versatile instrument of advanced design, are all the things you need for complete oscillographic recording. The Hathaway Type S-8 Oscillograph, which has long been the standard of oscillographic recording, has been improved to meet the rapidly expanding demands of modern research. Whether your measurement problems are simple or complex, the NEW Type S-8 Oscillograph has the inherent capabilities necessary to measure vibration, pressure, acceleration, and strain with new ease and accuracy.

The newest features include:

QUICK-CHANGE TRANSMISSION *fully enclosed with gears running in oil* **to provide instantaneous selection of 16 record speeds over the range of 120:1**

CHART TRAVEL INDICATOR provides continuous indication of chart motion. Operator knows instantly by flashing lamp if anything should happen to interfere with chart motion

FULL-RESILIENT MOUNTING FOR MOTOR AND TRANSMISSION isolates all possible vibration and makes possible the use of modern super-sensitive galvanometers

NEW GALVANOMETER STAGE accommodates *all* Hathaway galvanometer for recording milliamperes, microamperes, or watts

NEW RECORD-LENGTH CONTROL AND NUMBERING SYSTEM designed for long, trouble-free service under all kinds of ambient conditions

All the other valuable features are retained, such as

PRECISION TUNING-FORK-CONTROLLED TIMING SYSTEM produces either 1/10-second or 1/100-second time lines across sheet

WIDE RANGE OF GALVANOMETER TYPES AND CHARACTERISTICS provide for almost any recording requirements. Natural frequencies to 10,000 cps. Sensitivities to 50,000 mm per ma, single and polyphase watts

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12 TO 92 ELEMENTS

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This represents the actual size of the housing which totally encloses the Ulanet

MINIATURE THERMOSTAT

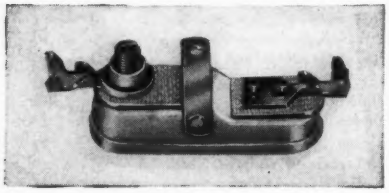
MODEL 13

Measure it!

Only 1" L x 5/16" W x 1/4" H

★ And into this tiny space a complete three-element thermostat is housed. Severe temperature changes can't strain the bimetal (principal cause of calibration changes) because of the special strain relief construction. Precision calibration is effected by extra fine threaded adjustment screw. Electrolytic silver contacts are used, too. Temperature ranges up to 400°F. are available.

Here's the mechanically rugged unit you should investigate for positive control. Ulanet engineers will be glad to help you if you state the application you have in mind.



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Precision Thermostats & Thermal Timers
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ELECTRIC HEAT CONTROL ENGINEERS

trochemical standard cell voltage of 1.018. Units in 0 to 100-v. range with current drains to 30 ma. are available. All operate on 90-130 v. 50-500 cps.—*Hastings Instrument Co., Inc., Super Highway at Pine Ave., Hampton* 10, *Va.*

Mention No. 431 when filling out card.

Hermetically-sealed VDR

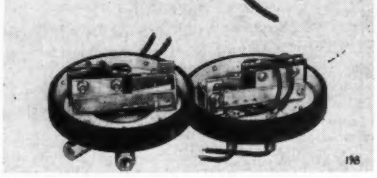
New "Models HS-75 and HS-100" are hermetically-sealed forms of maker's voltage-dividing rheostats. Units are available with 5 or 10 turns, power

ratings of 1 and 1.5 watts continuous, and resistances from 50 to 100,000 ohms. Tolerances of 0.5 percent overall and 0.1 percent linearity can be obtained. Instruments are helium filled.—*Van Dyke Instruments, Inc.*, 1927 *First Ave. S., P.O. Box* 355, *St. Petersburg* 1, *Fla.*

Mention No. 432 when filling out card.

Pressure-actuated Switch

New "Models 1620 and 1625" switches are pressure actuated; Model 1620 has minimum setting of 0.25 in. water with minimum differential of 0.2 in. water. Model 1625 has minimum differential



of 0.05 in. water. Slack diaphragm operates a 10-amp. 110-v. 60-cps. switch through a beryllium copper spring. Units operate on plus, minus, or differential pressure to 4 in. water. NPT connections 0.125 in. are provided.—*F. W. Dwyer Mfg. Co.*, 317 *S. Western Ave., Chicago* 12, *Ill.*

Mention No. 433 when filling out card.

Capacitors in 1500-volt Ratings

New "Cera-mite" disk capacitors with ratings as high as 1500 v. are among complete line of ceramic capacitors including temperature-compensating, general application and high-k types. 90 different standard ratings of capacitors are now available.—*Sprague Electric Co., North Adams, Mass.*

Mention No. 434 when filling out card.

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Downey, California

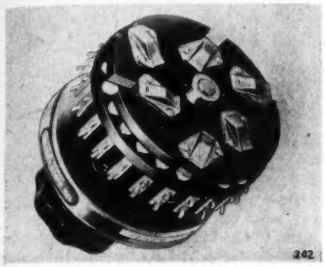
Deposited Carbon Resistors with Boron

New "Boro-Carbofilm" resistors include boron in deposited carbon film. Units have a temperature coefficient of 20 ppm. per deg. C. It is claimed they possess greater stability with a lower noise level; are available in ratings from 0.25 to 2 watts.—*Wilkor Products, Inc., 2882 Detroit Ave., Cleveland 13, Ohio.*

Mention No. 435 when filling out card.

Rotary Selector Switches

New models of maker's rotary selector switches are available with up to 6 poles, 15 positions per pole, on each

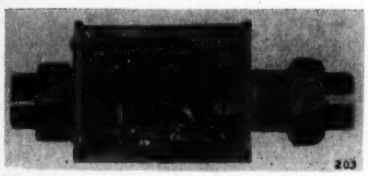


deck. Silver alloy contacts and rotor arms are used on all units. New roller-type detent is standard on all models. —*Daven Co., 191 Central Ave., Newark 4, N. J.*

Mention No. 436 when filling out card.

Flow Interlock

New improved flow interlock closes a contact when flow of water exceeds preset amount and opens it when flow falls below preset amount. Screw adjustment sets circuit for any flow from



0.5 to 4 gpm.; differential between cut-in and cut-out of electrical contact is 0.1 gpm. maximum. Unit has union fittings at each end and a strainer attachment; is intended only for cold-water applications. Switch is rated 10 amp. at 120 or 240 v. 60 cps.; body is rated 125 psi.—*Control Div., General Electric Co., Schenectady 5, N. Y.*

Mention No. 437 when filling out card.

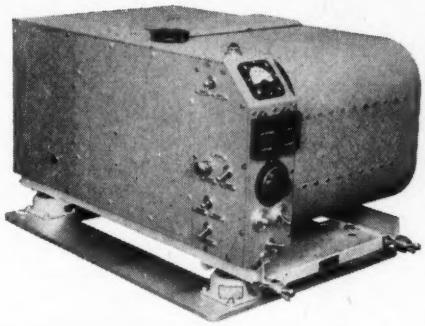
Scintillation Counter

New "Model CX 14" is self-contained alpha scintillation counter with inputs for external scintillation or G-M counters. Built-in counting chamber has geometry of 30 percent with 1.5-in. disk-mounted samples; background is 1-3 counts per hr. Sample chamber is $4 \times 4 \times 2$ in.; opening door removes high voltage from photomultiplier tube. Input sensitivity for external scintillation counter is adjustable from 0.0025 to 0.08 v.; G-M counter input sensitivity is 0.25 v. High voltage supply is regulated; is adjustable from 700 to 1500

Century INDUSTRIAL

RECORDING OSCILLOGRAPH

FOR VIBRATION, TEMPERATURE, STRESS, STRAIN ANALYSIS



MODEL 408 OSCILLOGRAPH

The Century Model 408 recording oscillograph was designed expressly for airborne and mobile operation. As with all Century products, this oscillograph incorporates the utmost in design and workmanship, along with improved features, yet it remains simple in its operation and maintenance.

FEATURES:

Size: 20" long, 12½" wide, 8⅞" high.

Weight: 60 pounds.

Number of Recording Channels: 6 to 50.

Detachable daylight loading magazine accommodating a roll of paper or film 8" x 200'.

Friction roller type paper drive by governor controlled electric motor with separate motor for takeup drive.

Paper speeds continuously and instantly variable without changing gears or sprockets.

Separate optical system for viewing before or during recording.

Glow tube timing system photographing .01 second and .1 second lines. .01 second lines instantly removable by toggle switch for slower speeds.

Data numbering at beginning of record.

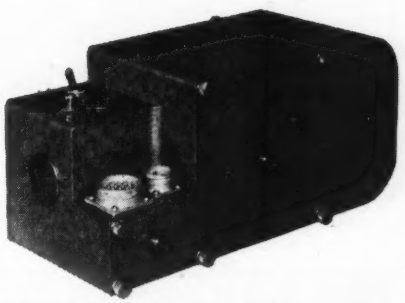
Footage indicator showing amount of paper remaining in magazine.

Automatic record length control.

Trace identification.

Remote control unit.

MODEL 409 OSCILLOGRAPH



The Century Model 409 oscillograph has been designed for recording data where space and weight requirements are limited. This oscillograph has been tested to record faithfully while subjected to accelerations up to 20 G's.

FEATURES:

Size: 5" x 5" x 11".

Weight: 11 pounds.

Cast Aluminum case.

Paper speeds variable ½" to 12" per second.

Detachable daylight loading magazine with a capacity of 3⅝" x 50' paper or film.

2 to 12 individual channels.

Trace identification.

Trace viewing.

For Complete Information Write 1340 North Utica

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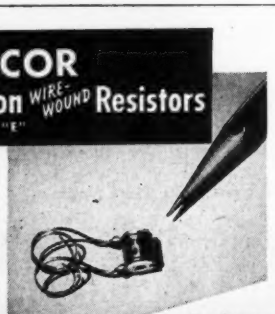
SERIES "E"



- High resistance plus high accuracy in miniature types.
- Standard temperature coefficient 0.000025 per degree C.
- Noninductive windings on ceramic bobbins.
- Nine types from 0.25 watt to 1 watt.

Series "E" HYCOR Precision Resistors are designed for use in applications requiring accuracy, stability and long life under conditions of extreme temperature variation plus moderately high humidity. For a slight additional cost they are supplied "tropicalized" against extreme humidity and fungus growths. All types are noninductively wound on nonhygroscopic bobbins with resistance wire having the lowest temperature coefficient available.

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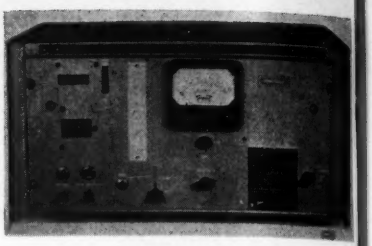


v. Panel-mounted clock and register are resettable. Instrument operates from 115-v. 60-cps. line. Over-all dimensions 10.75 × 22 × 15 in.; weight 50 lbs.—*R. C. Scientific Instruments Co., 335 Culver Blvd., Playa Del Rey, Calif.*

Mention No. 438 when filling out card.

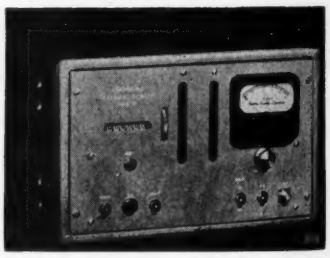
Line-noise Monitor

New "Model B-2" monitor warns when noise caused by transients on power line exceeds a preselected value. When selector is in "fast" position instrument detects noise pulses of 1 millisec. duration at a repetition rate of 50 kc. to 3 Mc. In "slow" position alarm will operate on noise continuous for 300 millisec. Sensitivity at 1 Mc. is variable from 0.25 to 8 v. Alarm indication is given by red light on panel; external bell may be connected. Instrument operates on 105-125 v.; over-all dimensions 14 x 7 x 8 in.; weight 20 lbs.—*Radioactive Products, Inc., 443 W. Congress St., Detroit 26, Mich.*

Mention No. 439 when filling out card.

Radioactivity Scalers

New "Models 100 and 110" scalers operate on scale-of-100, with capacity extended by mechanical register. High voltage control for G-M tube is adjustable from 0 to 2500 v. Maximum continuous counting rate is 1000 cps. Reso-



lution of random pulse pairs is 7 microsec. Model 110 is suitable for both G-M and scintillation counters; unit includes a predetermined counter. Both models have accessory outlets for external timer, time clock, and count rate meter. Over-all dimensions 9.75 x 10.75 x 14 in.—*Berkeley Scientific Corp., 2200 Wright Ave., Richmond, Calif.*

Mention No. 440 when filling out card.

Radioactivity Scaler

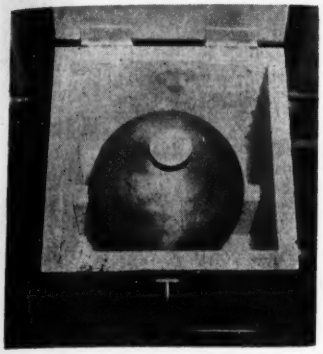
New "Model A-4" scaler is used with self-quenching counter tubes operating in Geiger region. Resolving time for negative pulse pairs is 5 microsec.; maximum input pulse height to preamplifier is 0.25 v. Regulated high voltage for counter tube is adjustable from 700 to 1400 v. Instrument can be started and stopped by remote control; external recorder, register, and timer

can be connected. Unit has panel-mounted 4-digit register; operates on scale-of-64.—*Radioactive Products, Inc., 443 W. Congress St., Detroit 26, Mich.*

Mention No. 441 when filling out card.

Container for Cobalt 60

New shipping and storage container for Cobalt 60 is available in 9- and 12-in. sizes. A solid lead ball has a central cavity to hold a hexagonal aluminum

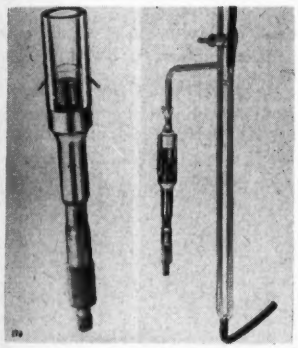


capsule 0.5 in. × 0.75-in. long containing Cobalt 60. A lead plug closes cavity. Balls are housed in wooden box; 9-in. ball weighs 200 lb., 12-in. ball weighs 300 lb.—*St. John X-Ray Laboratory, Califon, N. J.*

Mention No. 442 when filling out card.

Warburg Manometer Calibrator

New calibrator for Warburg manometers eliminates handling and weighing of mercury. Each division of micrometer scale of calibrator represents a volume displacement of 0.001



cc. Unit can be used wherever extreme accuracy is required to determine fluid or gas volume displacement of pipettes, microburettes, etc. Calibrator is furnished with an adapter to fit a standard taper. Plastic adapters are available to fit other size standard tapers.—*E. Machlett & Son, 220 E. 23rd St., New York 10, N. Y.*

Mention No. 443 when filling out card.

Dial Groove Gage

New dial gage is designed to measure diameter of internal grooves and recesses. Range adjustment is made by moving bottom plate within vernier range of desired position and setting on

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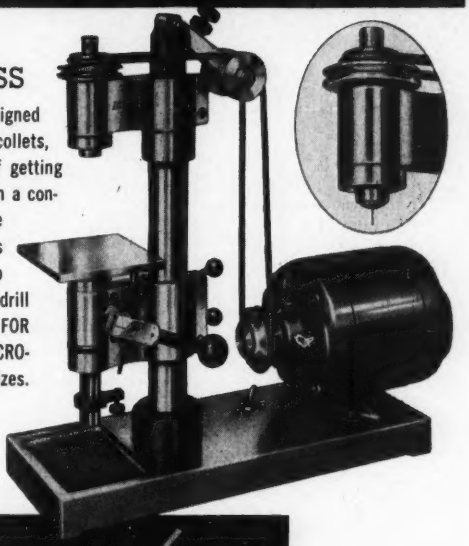
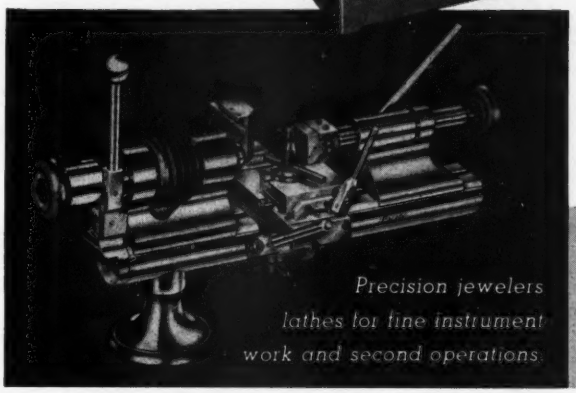
The Levin Micro-Drill Press is designed to hold small drills in precision collets, thus overcoming the difficulty of getting a drill to run true as when held in a conventional drill chuck. The absence of a sliding quill guarantees maximum sensitivity with fingertip control. A mounted ⅛" capacity drill chuck can also be used. WRITE FOR BULLETIN H DESCRIBING THE MICRO-DRILL PRESS and listing collet sizes.

for drilling holes as small as .002"





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3. You get precise positioning of the moving contact because of the two bearings supporting the rotor assembly.
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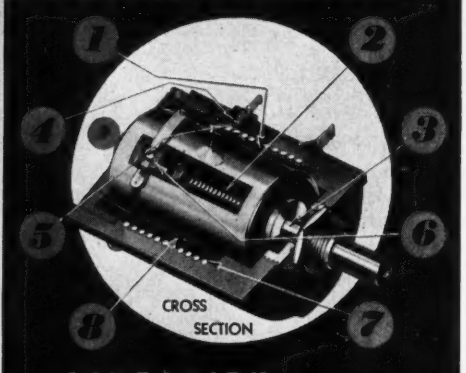
7. You get a fine resolution because of the 43½" length of resistance wire in the spiral element.
8. You get a resistance output directly proportional to shaft rotation within ±0.1% of the total resistance. Every potentiometer is automatically machine tested for linearity at 101 points.



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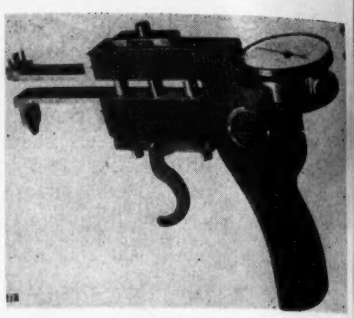
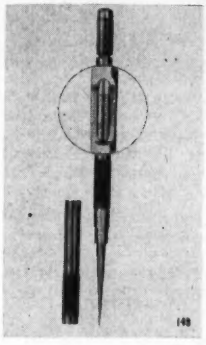


gage blocks, micrometers, or master check ring.—*Nilsson Gage Co., Lake St., Poughkeepsie, N. Y.*

Mention No. 444 when filling out card.

Glass Tubing Gage

New glass tubing gage has a micrometer scale with vernier for inside measurements from 0.01 to 5 mm. It can also be used for measuring bores

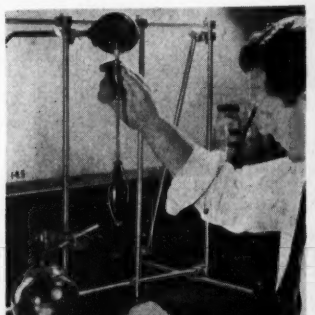


or circular openings. Needle is hardened steel and a needle cap is provided to protect point when not in use.—*E. Machlett & Son, 220 E. 23rd St., New York 10, N. Y.*

Mention No. 445 when filling out card.

Laboratory Stirrer

New "Umbrella Stirrer" can be closed to insert in flask, then opened. All parts



of stirrer are made of corrosion-resistant stainless steel; shaft is 0.25 in. diameter.—*Fischer Scientific Co., 717 Forbes St., Pittsburgh 19, Penna.*

Mention No. 446 when filling out card.

Shuttle Tension Tester

New shuttle tension tester has small electric motor which rewinds yarn

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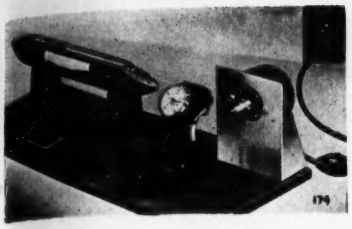
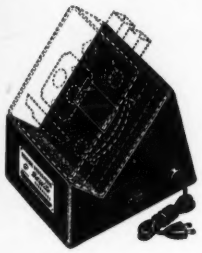


through maker's tension indicator. Adjusting means in shuttle can be set to produce desired tension.—*Saxl Instrument Co., Harvard, Mass.*

Mention No. 447 when filling out card.

Comparator Illuminator

New "Daylite" illuminator now available for maker's pocket and standard comparators provides suitable light for colorimetric work. Unit is equipped

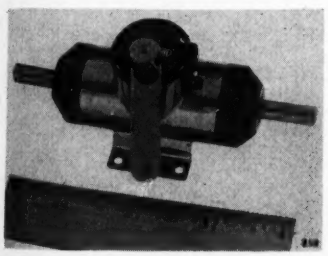


with specially-coated bulb and Corning daylight glass filter. Ventilated metal housing measures 3.75 × 4.75 × 3.75 in.; sloping front holds comparator at angle of 45 deg. Furnished for 110-125 or 220-230 v., alternating or direct.—*Hellige, Inc.*, 3718 *Northern Blvd., Long Island City* 1, *N. Y.*

Mention No. 448 when filling out card.

Miniature Variable-speed Drive

New "Type 4B" variable-speed drive has a lever for adjusting speed ratio. Unit has ratings to 2 lb.-in. torque,



0.025 hp., 20,000 rpm., and ratio is infinitely variable from 0.17 to 6. New type is designed for applications requiring remote or automatic control. —*Metron Instrument Co.*, 432 *Lincoln St., Denver* 9, *Colo.*

Mention No. 449 when filling out card.

Flow Control Elements

New calibrated flow control elements, used principally to provide time delays in instrument operations are fabricated from porous stainless steel filter material. Units are assembled into brass or stainless steel housings with threaded connections; an element having a flow

MICRODIAL

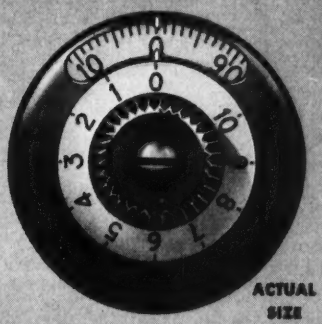
TEN TURN-COUNTING DIAL

Microdial is composed of two concentrically mounted dials . . . one for counting increments of each turn and the other for counting turns. The incremental dial has 100 equal divisions and is attached rigidly to the shaft so there is no backlash. Thus the contact position is indicated to an indexed accuracy of 1 part in 1000. Rotation is continuous in either direction. There are no stops on the Microdial assembly.

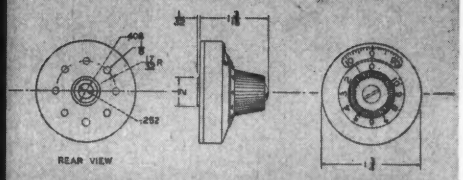
COMPACT . . . Microdial has same O.D. as Micropot . . . requires no more panel space.

CLEAR READING . . . Forced fast-reading tests showed only 1/20th as many errors with Microdial open window as with next most legible dial. Turn counter distinguishes between 0 and 10 turn readings, and accelerates to avoid confusion on readings near integral turns. Precise readings are made from larger dial with maximum separation of graduations and wide angle visibility.

CONVENIENT . . . delivered completely assembled with dials synchronized. Easily mounted in a few seconds. All dials may be locked.



ACTUAL SIZE



REAR VIEW

Microdial . . . turn-counting dial, primarily designed for use on Micropot ten turn linear potentiometers . . . use it on any multiturn device having ten turns or less.

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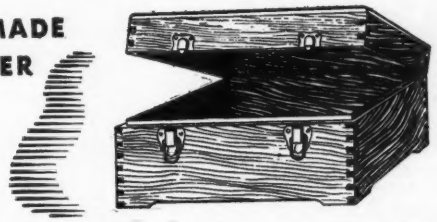

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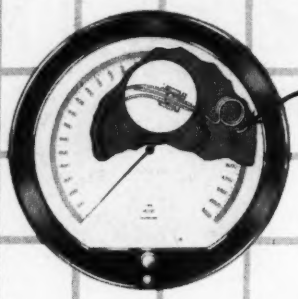

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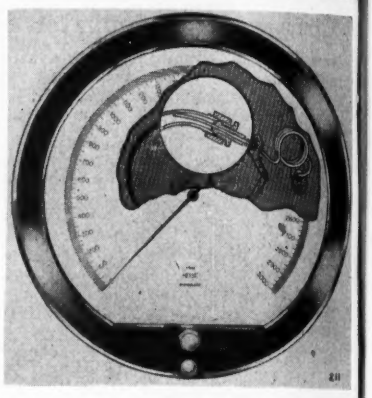
of 5 cc. of air per min. at 10 psi. differential fits into a cylinder 0.25 in. diameter by 1-in. long. Flows are calibrated at differential pressures equal to those used in the instrument and are held to required tolerance.—*Micro Metallic Corp., 30 Sea Cliff Ave., Glen Cove, N. Y.*

Mention No. 450 when filling out card.

Air Bleed for Bourdon Tubes

New air bleed for maker's Bourdon tubes extends from highest point in tube to external block containing vent screw



on back of case. Removal of screw permits all air to escape; when pressure medium reaches vent screw is replaced and gage is ready for use.—*Heise Bourdon Tube Co., Inc., Newtown, Conn.*

Mention No. 451 when filling out card.

Snap-action Thermostat

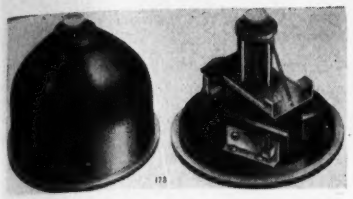
New "Type W" snap-action thermostat operates with a fixed differential as close as 5 F. in a 400 F. range. Units are non-radio-interfering and feature

an electrically independent bimetal. Stainless steel contact spring is crimped along its outer edges so that positive pressure is exerted on contacts until they snap open.—*Stevens Mfg. Co., Inc., 69 S. Walnut St., Mansfield, Ohio.*

Mention No. 452 when filling out card.

Surface-type Thermostat

New "Thermoray" surface-type thermostat is sensitive to both convection air and radiant panels. Unit is part

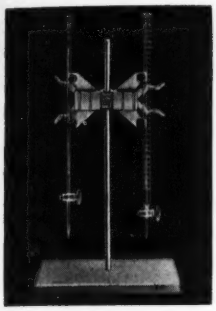


of maker's control system for hot-water radiant heating and can be used in line or low-voltage circuits. Double switch action can be furnished.—*Sarcotherm Controls, Inc., Empire State Bldg., New York* 1, *N. Y.*

Mention No. 453 when filling out card.

Double Burette Holder

New double burette holder of cast aluminum alloy has an aluminum support rod and white porcelain base. Holder does not obscure graduation



lines, numbers or meniscus level; unit accommodates burettes from micro to 100 ml. capacity.—*Laboratory Industries, Inc.,* 4710 *W. North Avenue, Chicago* 39, *Ill.*

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Electric Counters

New "Model Y" electric counter measures 1.38 x 2.56 x 3.75 in.; operates at speeds up to 1000 counts per min. New "Model CS" counter is 2.38 x

4.25 x 5 in. over-all; operates up to 800 counts per min. Both are available in 6 figures and are resettable; standard voltage is 110 v. 60 cps.—*Durant Mfg. Co.,* 1914 *N. Buffum St., Milwaukee* 1, *Wis.*

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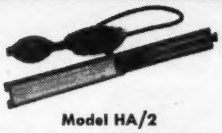

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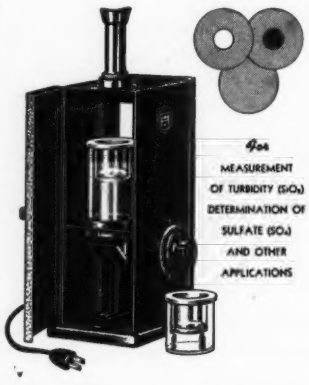

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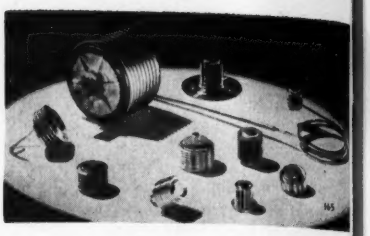

ply construction. A variety of end fittings can be attached by seam welding, silver brazing, or soldering. Complete assemblies can also be supplied.—*Chicago Metal Hose Corp.*, 1316 *S. Third Ave., Maywood, Ill.*

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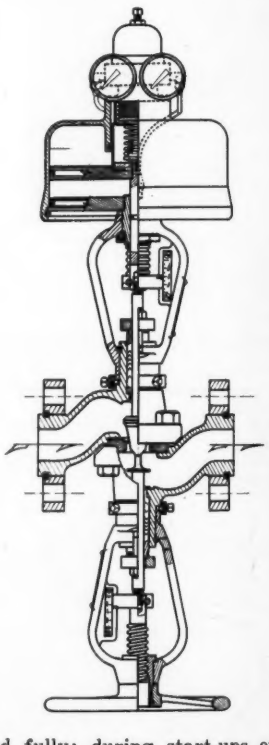
Combination Automatic Manual-control Valve

New combination valve uses maker's "Domotor" operator and "Fig. 15" handwheel mounted on underside of single seated valve body. When automatic control is desired handwheel valve is

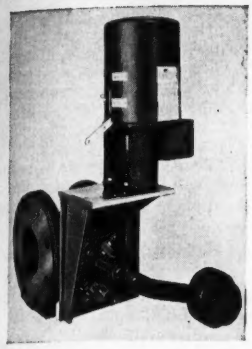


opened fully; during start-ups or instrument repair periods handwheel provides manual control without changing valves. Handwheel may also be used as an adjustable limit stop for automatic control valve plug. Valves are rated to 3000 psi. and 1000 F.—*Annin Valve Co.*, 3500 *Union Pacific Ave., Los Angeles* 23, *Calif.*

Mention No. 457 when filling out card.

Rubber Lined Valve

New "No. 763" butterfly valve has a cast iron body and is rubber seated. Angular seating vane for wedge type closure compresses rubber around periphery of vane to give positive shut-off even around shaft bosses. Rubber



flanges take place of flange gaskets. Valve is operated by directly-connected motor-driven pump, sealed in oil. Hydraulic pressure raises counter-weight for open position; when valve is fully open, operating motor is cut off by integral switch. Should current fail, oil operator is released, counter-weight drops, and valve closes. Sizes range from 2 to 72 in.—*R-S Products Corp., 4600 Germantown Ave., Philadelphia 44, Penna.*

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Solenoid Valve

New solenoid valve for pneumatic applications has a clapper-type solenoid and pistons and poppets are tied together in one unit. Solenoid cover is

hinged. Valve body is rated to 125 psi.; is available from 0.25 to 1.25 in. 2- or 3-way normally-open or closed.—*Ross Operating Valve Co., 120 E. Golden Gate, Detroit 3, Mich.*

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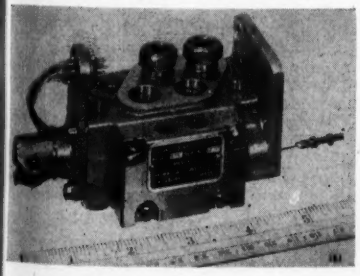
Servo Control Valves

New "Models MX and XA" servo control valves operate in hydraulic systems up to 3000 psi. and have maximum



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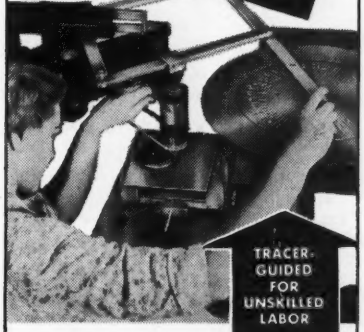

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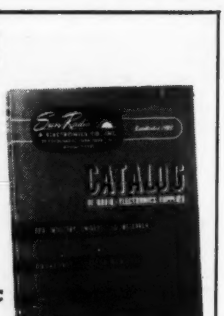

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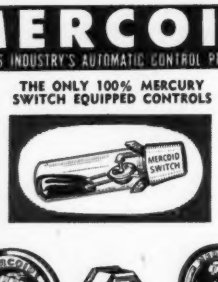

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power outputs of 5 and 2.5 hp. respectively. Pilot valve operates from electromechanical units which have 0.004-in. displacement with 4-lb. force. Position of power piston is measured by a linear variable transformer. Units have low dither level and continuous linear output down to displacements of 0.0001 in., maker states. Over-all dimensions 2.38 × 2.69 × 4.56 in.—*Hydraulic Controls Co., 87 Terrace St., Roxbury 20, Mass.*

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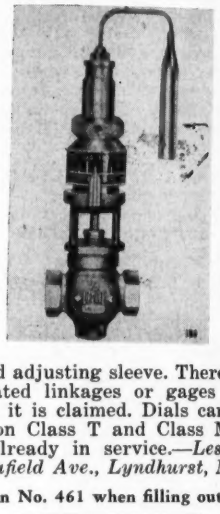
Calibrated Dial for Temperature Regulators

New calibrated dial for use with maker's "Class T" and "Class M" temperature regulators fits in place of



standard adjusting sleeve. There are no complicated linkages or gages to add friction, it is claimed. Dials can be installed on Class T and Class M regulators already in service.—*Leslie Co., 225 Delafield Ave., Lyndhurst, N. J.*

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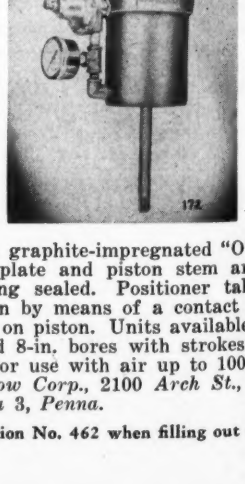
Pneumatic Cylinders

New "Series B-50" pneumatic cylinders consists essentially of an "O"-ring-sealed piston with a positioner integrally mounted in head plate. Cylinder itself is cast aluminum; piston is fitted



with a graphite-impregnated "O" ring. Head plate and piston stem are also "O"-ring sealed. Positioner takes its position by means of a contact spring riding on piston. Units available in 4-, 6-, and 8-in. bores with strokes up to 4 in. for use with air up to 100 psi.—*Conoflow Corp., 2100 Arch St., Philadelphia 3, Penna.*

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REMOTE SUPERVISION

Continued from page 405

supervision, where a maximum of dependability is paramount.

Transforming Impulse to Signal

So far, the receiver has been mentioned merely as a mechanism which receives impulses from the transmitter, and prints corresponding dashes on a paper tape. The receiver is indicated in Fig. 9 by a relay coil.

There are, of course, many methods by which the impulse into the relay coil can be transformed into a signal. Instead of the dash-marking recorder, for example, a punch recorder which punches or slashes holes into a paper tape might be used. Other equipment such as bells, buzzers, lights and numbers on an annunciator panel may augment or replace the recorder. A time stamp may be added to the recorder to register the time at which a signal is received.

In some very complex signalling systems, recorders which translate coded signal impulses into printed-in-words information are used. All this can be developed once the impulse in the recorder relay is received. This will start the paper tape rolling for a predetermined time, it will actuate the printing mechanism, time stamp, and whatever else is to go with it.

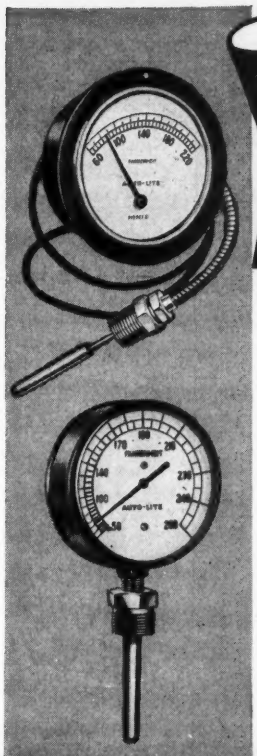
This completes an outline of the remote supervision of one industrial process, starting with the action of a pressure switch in response to excessively high pressure and ending with the receipt of the signal at the central station. A maximum of reliability is achieved through providing supervision of far more complex conditions than the fluctuation of pressure in a single tank.

Conclusions

In an editorial in *Instruments*, December 1948, M. F. Behar wrote: "What we predict is an instrument which will (1) make immediate "joint" or "integrated" reports on the time functions of the readings of the numerous already-installed measuring AND automatic-control instruments; and (2) immediately carry out IN DETAIL the logical BROAD decisions of the human supervisor."

There are still a couple of laboratory miles to go towards the fulfillment of this prediction, but we are on the road. Much has been achieved, so far, especially for heating plants, where pressure, water, various burner conditions, etc., are to be supervised. A detailed description of such supervisory systems would, of course, require a separate article.

The present-day centralization of the human element required for supervision of industrial processes as described above is a perfect integration of electrical and mechanical instruments with the human element—and, although not completely mechanical, does accomplish the desired ends outlined by Mr. M. F. Behar's prediction.



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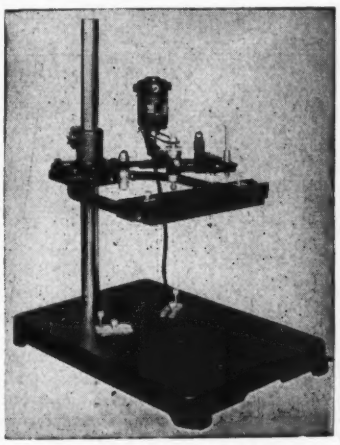

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THE DIRECT-READING D-C. STRAIN-GAGE BRIDGE

Continued from page 401

cedure in order to determine the direction and magnitude of the maximum shear stress.

There are many variations of the bridge types presented in this discussion. Ordinarily only one strain gage is used for each bridge arm, but two or more gages may sometimes be used to advantage. A simple variation would be to use two 60-ohm gages in series for a strain-gage arm. Such a bridge arm would have 120 ohms resistance and could be used to measure the average strain between two points and/or the pair could cancel a secondary bending effect. More complicated bridge arrangements may be obtained by series-parallel wiring of gages. Many gages may be used for a single bridge arm in this way. Bridges may be arranged with predetermined sensitivities to different strains at different locations. For example, a bridge could be wired so that a strain at one gage location would produce twice as much effect on the bridge output as the strain at another location or at any of several other locations, etc. Secondary bending could be canceled at one location while axial strains were canceled at another location. Shear,

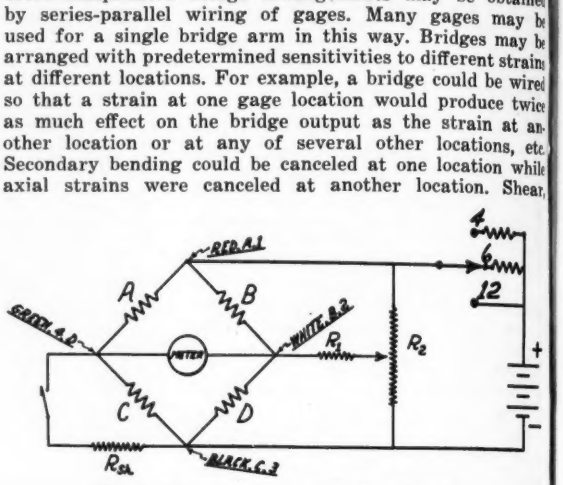

Fig. 7. Schematic of a strain-gage channel.

bending and axial strains could be used to unbalance a bridge as desired. The arrangement used for any special application would, of course, depend upon the effect desired.

Calibration of Bridges

This discussion of the calibration of strain-gage bridges will be divided into two parts: Resistance Calibration and Force Calibration. The reduction of strain-gage data will be described in these discussions. For clarity, the discussion of resistance calibration will begin with an explanation of the fundamental principle involved in the operation of a strain gage.

Resistance Calibration

The operation of a bonded resistance-wire strain gage requires an instrument which responds to any change in resistance of the strain gage. Many different kinds of recording and indicating instruments may be used. Any strain experienced by the strain gage causes a change in its resistance. Since the gage is securely bonded to the surface of a test specimen, it suffers the same strain as does the surface of the specimen at the place of attachment. The deflection of the instrument is proportional to the strain of the gage.

The most popular method of calibration is to shunt one arm of the strain-gage bridge with a known high resistance R_{sh} as shown in Fig. 7. This produces a known change of resistance of the bridge arm and a definite instrument deflection.[3] (As a matter of interest, the resistance change of a 120-ohm strain gage during ordinary testing is usually considerably less than one ohm).

Before measuring strains, it is necessary to determine the magnitude of strain that will produce the same change in gage resistance as that produced by a given calibration resistance. This is called the equivalent strain for a given calibration resistance. From this equivalent strain and the deflection produced by a resistance calibration, the strain corresponding to any instrument deflection can be calculated.

(3) In Fig. 7, resistors R_1 and R_2 are shown; their purpose is to establish balance of the bridge circuit. These resistors must be as stable as any other elements of the circuit if performance is not to be sacrificed.

The observed strain will be equal to the product of the instrument deflection and the equivalent strain divided by the instrument deflection caused by the calibration resistance.

For a given combination of calibration resistance and bridge arm resistance, the deflection for a resistance calibration depends principally upon the bridge voltage and the instrument sensitivity, although if the instrument is a current-sensitive device, its resistance is also an important factor.[4] A resistance calibration is essentially a calibration of all of the instrumentation of the strain-gage bridge. Several resistance calibrations are often taken during a test to check the stability of the instrumentation. The instrument deflection produced by the resistance calibration should remain the same throughout a test. This stability is more easily obtained when the instrumentation is as simple and straightforward as possible.

In a test employing many strain-gage channels, it is necessary to make a resistance calibration for each recording or indicating instrument used. When a multi-channel oscillograph is used, a resistance calibration must be made for each galvanometer. In dynamic testing separate instruments are usually used for each strain-gage bridge; this requires a resistance calibration for each strain-gage bridge. When several bridges are read on a single instrument, it is necessary to calibrate only one, providing all have the same resistance.

When strain gages are used to measure strain, a resistance calibration is the only one that is necessary, since a strain gage has a definite strain sensitivity known as its gage factor or gage constant. The gage factor C for each strain gage is supplied by the manufacturer. The term gage factor can be defined by the common equation:

$$C = \frac{\Delta R/R}{\Delta L/L} = \frac{\Delta R/R}{e} \qquad (2)$$

From this equation it can be seen that the sensitivity of a strain-gage bridge is proportional to the gage factor of the gages in the bridge—the higher the gage factor the greater the instrument deflection for a given strain.

As discussed previously, a known change of resistance ΔR may be obtained with a known calibration resistance R_{sh}. By algebraic reduction using standard formulas, the ratio $\Delta R/R$ may be written as $R/(R + R_{sh})$. By substituting this ratio in the equation for gage factor and transposing the equation, we obtain an equation for determining the strain necessary to produce a change of gage resistance equal to the change of gage resistance produced by a known calibration resistance. This is called equivalent strain; the equation is:

$$(\text{equiv.})\ e = \frac{R}{C\ (R+R_{sh})}$$

For example: A 30,000-ohm resistance shunted across a 120-ohm gage having a gage factor of 2.00 would produce a change of gage resistance equal to that produced by a strain of approximately 0.002 inches per inch.

The equation just given applies only when one arm of the bridge is active, because only one arm of the bridge is shunted by the calibration resistance R_{sh} (See Fig. 7). The bridge output may be doubled by using four active gages, as can be done in measuring bending strains. (This is possible because in bending we have strains of opposite sign. A tension strain is regarded as being positive and a compression strain negative. If the strains are of different signs, adjacent arms of the bridge are used. If the strains are of the same sign, opposite arms of the bridge must be used. This rule applies throughout the following discussion).

On the basis of the gage factor supplied by the manufacturer and the number of active arms N of the bridge used, we may extend our equation for equivalent strain to

$$(\text{equiv.})\ e = \frac{R}{C\ N\ (R + R_{sh})}$$

This equation, however, must be qualified. It is valid only if all the active gages are used in the same manner in which

(4) A current-sensitive instrument is one whose resistance is low compared to that of the rest of the circuit; a voltage-sensitive instrument is one whose resistance is high compared to the rest of the circuit.

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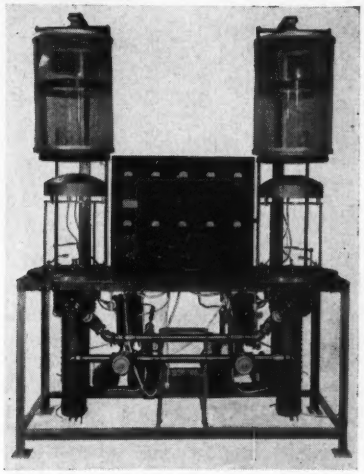

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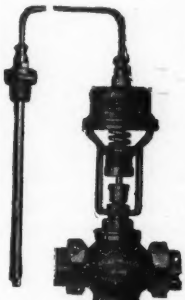

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their gage factors are determind by the manufacturer. Solving this equation yields the indicated or apparent strain. When the ratio of indicated strain to actual strain is unity this equation may be used for determining equivalent strain. The above equation will work for any bridge if we substitute a symbol N_E (which represents the effective value of the number of active arms) for the symbol N. However it is in order to discuss the meaning of this new symbol before presenting the equation.

As mentioned in the discussion of bridge type A3, nearly all strain gages (because of their inherent construction) have a small transverse sensitivity as well as axial sensitivity. These sensitivities are resistance sensitivities to strain, expressed as ohms-per-ohm per inch-per-inch. The ratio of transverse to axial sensitivity has been designated as b. Because of this transverse sensitivity, the gage factor or strain sensitivity of a strain gage is not the same as that of the fine wire used in its construction. The transverse sensitivity of a strain gage responds to the transverse strain, or the strain perpendicular to the axis of the gage. If a gage is mounted in a uni-axial stress field with its axis in the direction of the stress, the transverse strain is equal to Poisson's ratio u for the material multiplied by the axial strain e_x. Referring to the equation for gage factor, equation (2), the value of $\Delta R/R$ may be regarded as the algebraic sum of the $\Delta R/R$ produced by the axial sensitivity and the $\Delta R/R$ produced by the transverse sensitivity. The output of a strain-gage bridge is a function of its unbalance, and is proportional to the ratio $\Delta R/R$. The gage factor is determined by the manufacturer for a definite $\Delta R/R$ condition and is valid only for that condition. In order for a strain gage to meet this condition, it must be bonded in a uni-axial stress field with its axis in the direction of the stress. If one or more strain gages in a strain-gage bridge are not mounted in this way, the indicated or apparent strain is not equal to the actual strain. A condition in which the indicated strain is not the actual strain may be caused by either or both of the following conditions:

(1) A strain gage is mounted in a bi-axial stress field.

(2) A strain gage is mounted in a uni-axial stress field with the axis of the gage not parallel to the direction of the stress.

Examples of these conditions are found in all of the bridges presented in the discussion of bridge types except for bridge types A1 and B1. When strain gages are used for measuring axial and bending strains in a uni-axial stress field with their axes in the direction of the stress, the actual strain and the indicated strain are equal. Bridges A1 and B1 are examples of bridges using strain gages in this manner. For these bridges the ratio of indicated to actual strain is unity, but this is not true for bridge types A2, A3, and S1. Thus we see that for bridge types A1 and B1 the effective value of the number of active arms equals the number of active arms ($N_E = N$), while for bridge types A2, A3, and S1 the effective value is not the same as the actual value, (N_E not equal to N).

We may write a general equation for equivalent stress from the basic stress relationship $f = eE$ as

$$(\text{equiv.})\ f = \frac{R\ E}{N_E\ C\ (R + R_{sh})} \qquad (3)$$

E is the modulus of elasticity and this equation applies to all bridge types presented here except the S1 bridge. For the S1 bridge a value of twice the modulus of rigidity (2 G) must be substituted for E. An equation for equivalent shear stress may be written as

$$(\text{equiv.})\ f_s = \frac{R\ 2\ G}{N_E\ C\ (R + R_{sh})} \qquad (4)$$

Proof of the validity of the substitution of 2 G for E in order to determine equivalent shear stress is not presented here, but may be proven by the reader from an examination of the shear bridge used here and of Mohr's Circle for mutually perpendicular stresses.

N_E (the effective value of N) may be defined as the effective value of the number of active arms in the bridge based

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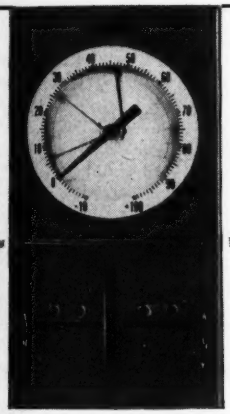

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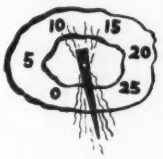

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upon the output of the bridge and the gage factor supplied by the manufacturer. The value of N_E may be expressed as

$$N_E = \frac{e_t}{e_x}$$

e_x = The actual strain the bridge is being used to measure.

e_t = The total strain indicated by the bridge output and based upon the gage factor supplied by the manufacturer. See Eq. (2). The indicating or recording instrumentation responds to the total ($\Delta R/R$) of all the active gages of the strain-gage bridge.

In Fig. 8 e_t is plotted against e_x for each of the five bridge types discussed. The slope of the line for each bridge

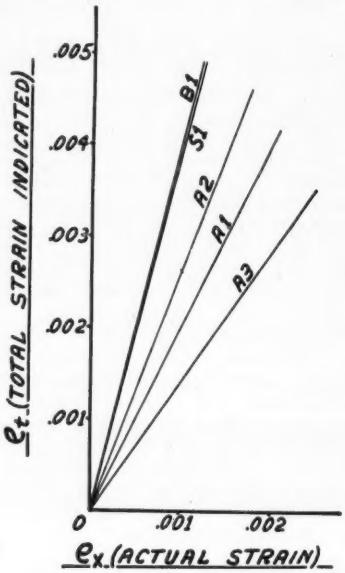


Fig. 8

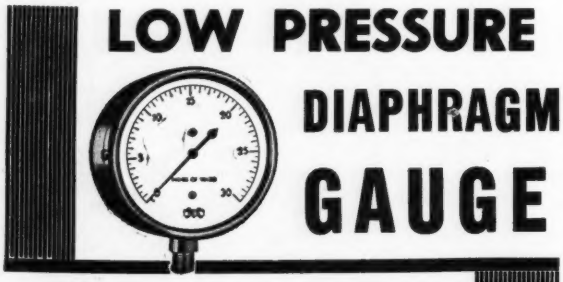
is equal to the value of N_E for that bridge. For the convenience of the reader, a table is presented giving the value of N and N_E for all five bridge types previously discussed.

Bridge Type	N	*Effective Value of the Number of Active Arms, N_E*
A1	2	$N_E = N = 2$
A2	4	$2(1+u-b)$
A3	2	$2(1-u)$
B1	4	$N_E = N = 4$
S1	4	$4 \times 30/31 = 3.87$

The ratio 30/31 used in connection with the value of N_E for an S1 bridge is derived from information supplied by the manufacturer and may be checked mathematically as well as experimentally. It is customary for the manufacturer to furnish with standard "X" type shear gages (AX-5) a statement that the actual strain equals the indicated strain minus 1/30 the indicated strain.

In determining the equivalent stress for the A3 bridge or "stress gage," the strain is multiplied by the modulus of elasticity, as mentioned previously. Some explanation may be in order since we are measuring stress in a bi-axial stress field; however, proof of this is not given since it would involve considerable discussion and might not be of interest to many readers. Suffice it to say that the strain obtained in equation (3) for the A3 bridge is that strain which when multiplied by the modulus of elasticity yields the stress.

When strain gages are used extensively, the determination of equivalent stress may be simplified considerably by making up a table of all the bridge types used and listing the equivalent stresses for the different combinations of gage factor, calibration resistance, and test material that may be encountered. An example of such a table appears in Fig. 9. Equations (3) and (4) were used to determine the values in this table. Similar tables for bridges using other gage resistances may be prepared.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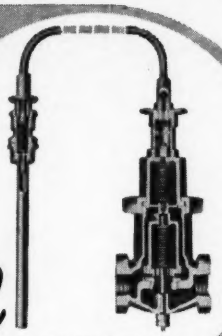

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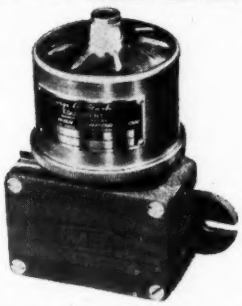

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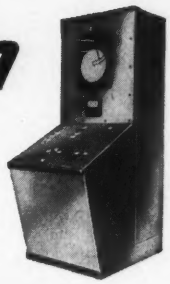

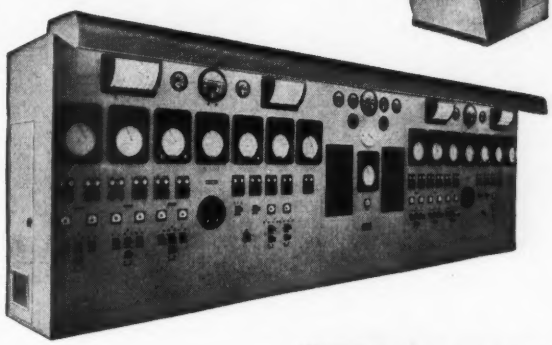

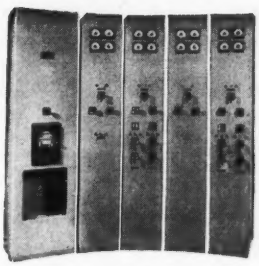

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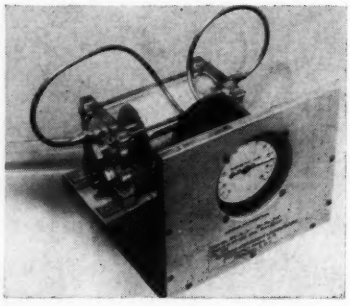

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Table of Equivalent Stresses for Bridges with 120-Ohm Arms - Values in psi.

Gage Factor	Calibration Ohms	Axial A1 Alum.	Axial A1 Steel	Axial A2 Alum.	Axial A2 Steel	Bending B1 Alum.	Bending B1 Steel	Shear A1 Alum.	Shear A1 Steel
1.90	100,000	3312	9147	2559	7288	4943	12683	1656	4573	1287	3965
	30,000	11008	30405	8500	24229	16431	42874	5504	15202	4279	11819
1.91	100,000	3294	9099	2543	7250	4917	12616	1647	4550	1281	3946
	30,000	10951	30246	8457	24100	16345	42599	5476	15125	4257	11756
1.92	100,000	3277	9052	2531	7212	4892	12749	1639	4528	1274	3926
	30,000	10894	30088	8412	23974	16260	42377	5447	15044	4235	11693
1.93	100,000	3260	9005	2518	7175	4866	13443	1630	4503	1267	3907
	30,000	10838	29932	8369	23850	16176	42156	5419	14967	4213	11631
1.94	100,000	3243	8958	2504	7138	4841	12819	1622	4479	1261	3888
	30,000	10781	29778	8325	23727	16092	41941	5391	14889	4191	11572
1.95	100,000	3227	8912	2493	7101	4815	12853	1614	4455	1254	3869
	30,000	10726	29626	8283	23606	16010	41725	5363	14813	4170	11514
1.96	100,000	3210	8867	2479	7065	4793	12889	1606	4433	1248	3476
	30,000	10672	29474	8241	23485	15928	41513	5336	14737	4148	11503
1.97	100,000	3194	8822	2466	7029	4767	12925	1597	4411	1242	3456
	30,000	10618	29324	8199	23367	15847	41302	5309	14662	4127	11494
1.98	100,000	3178	8777	2454	6994	4743	12962	1589	4389	1235	3440
	30,000	10563	29176	8158	23249	15767	41093	5282	14588	4106	11436
1.99	100,000	3162	8733	2442	6959	4719	12900	1581	4367	1229	3423
	30,000	10511	29030	8118	23131	15688	40887	5256	14515	4086	11378
2.00	100,000	3146	8690	2429	6924	4696	12939	1573	4345	1223	3406
	30,000	10459	28884	8078	23015	15610	40682	5230	14443	4065	11320
2.01	100,000	3131	8646	2418	6890	4672	13178	1566	4323	1217	3389
	30,000	10406	28741	8038	22901	15532	40480	5203	14370	4045	11262
2.02	100,000	3115	8602	2406	6855	4649	12718	1558	4302	1211	3372
	30.000	10355	28598	7998	22788	15455	40280	5178	14298	4025	11205
2.03	100,000	3100	8561	2394	6822	4626	12068	1550	4281	1205	3355
	30,000	10303	28456	7958	22675	15379	40081	5152	14226	4005	11149
2.04	100,000	3085	8519	2382	6788	4604	11968	1543	4260	1199	3338
	30,000	10253	28316	7917	22564	15304	39885	5127	14159	3985	11093
2.05	100,000	3070	8478	2371	6755	4581	11940	1535	4239	1193	3322
	30,000	10203	28180	7879	22454	15229	39690	5102	14092	3966	11038
2.06	100,000	3055	8437	2359	6722	4559	11912	1528	4218	1187	3307
	30,000	10154	28043	7841	22345	15155	39497	5077	14025	3947	10992
2.07	100,000	3040	8396	2347	6690	4537	11885	1520	4198	1182	3291
	30,000	10104	27908	7803	22237	15081	39307	5053	13958	3928	10939
2.08	100,000	3025	8355	2336	6658	4515	11968	1513	4178	1176	3276
	30,000	10056	27774	7765	22130	15009	39118	5028	13887	3909	10886
2.09	100,000	3011	8315	2325	6626	4494	11712	1506	4158	1170	3260
	30,000	10008	27641	7728	22024	14937	38930	5004	13820	3890	10834
2.10	100,000	2996	8276	2314	6594	4472	11656	1498	4138	1165	3244
	30,000	9960	27509	7691	21920	14866	38745	4980	13755	3872	10782

Notes: (1) Alum. values are for aluminum alloys, properties as follows; E = 10.5 X 10^6, G = 3.95 X 10^6, and μ = .33.
(2) Steel values are for austenitic steel, properties as follows; E = 29 X 10^6, G = 11 X 10^6, and μ = .29.
(3) Values for stainless steel may be obtained by multiplying the values given for steel by 29/29.
(4) Values given for A2 and B1 bridges are for AK-5 gages.

Fig. 9

The purpose of a force calibration is two-fold:

(1) To determine the linearity of output of the device; this may be plotted as unit load vs. unit output of instrument deflection.

(2) To determine the force necessary to produce a resistance unbalance of the bridge equal to that produced by a known calibration resistance. This is accomplished by a resistance calibration.

The first purpose is accomplished by loading the device in increments and plotting load against the deflection of the indicating instrument. Fortunately, this plot is generally a straight line, indicating that the output of the device is a linear function of the applied load. This calibration may be completely expressed as a certain magnitude of force per given calibration resistance. For example, the calibration of a cantilever beam used to measure deflection might be expressed thus: 0.47 inches/30,000 ohms. Such an expression cannot be used for the calibration of a strain-gage device if the load vs. bridge-output plot is not a straight line. Rather, the curved plot of load vs. output showing the bridge output for a given calibration resistance will have to be used. Test data from such a device can best be reduced by reading the force directly from the calibration curve. Of course, it is necessary to correct the bridge output obtained during the test by multiplying it by the ratio of the bridge output obtained from a resistance calibration at the time of the force calibration to the bridge output obtained from a similar resistance calibration taken during the test.

When strain gages are used extensively, expressions such as "equivalent load in pounds," "equivalent deflection in inches," and "equivalent stress in psi." may be found cumbersome. It has been found convenient to use the term

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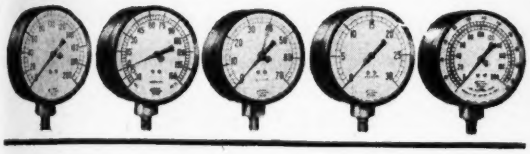

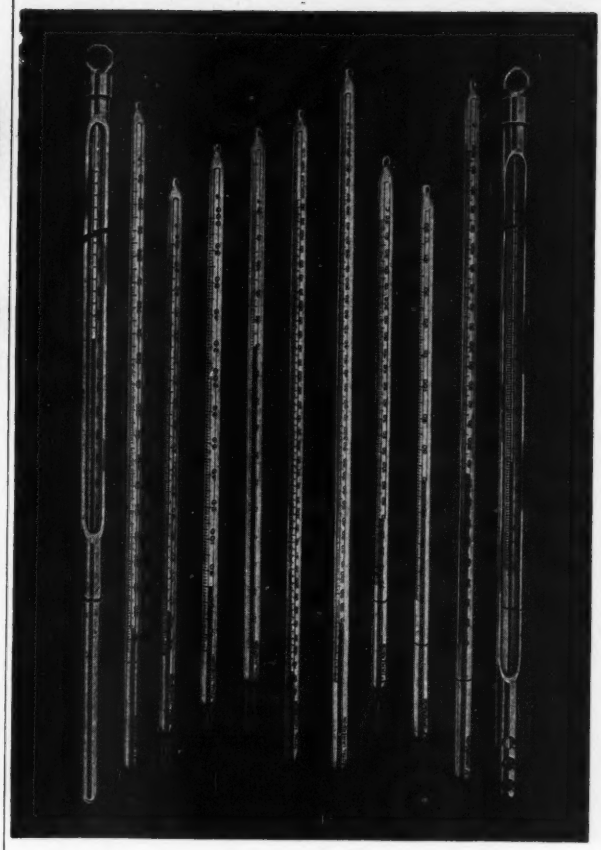

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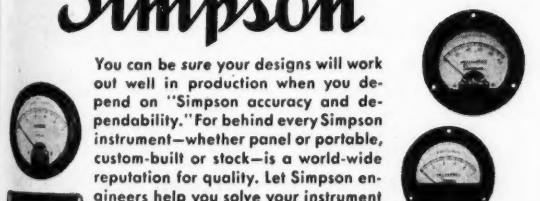

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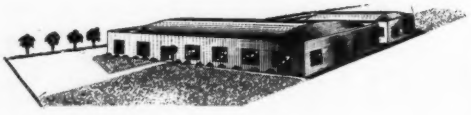

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"Factor" to express an equivalent force or stress. Su expressions can then be more simply stated as "Factor pounds," "Factor in inches," or "Factor in psi." The ca bration of a load ring, for example, might then be expres as: Factor = 440 lbs./30,000 ohms.

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Quantity being measured

$$= \frac{\text{Factor} \times (\text{instrument deflection})}{\text{calibrate unbalance}}$$

The instrument deflection is that resulting from the mea urement. The Factor must be in the same units as th quantity being measured (psi., lbs., etc.). The "calibra unbalance" is the instrument deflection produced by a re sistance calibration taken at the time of the test. This re sistance calibration must be made with a resistance of th same value as that for which the Factor is valid.

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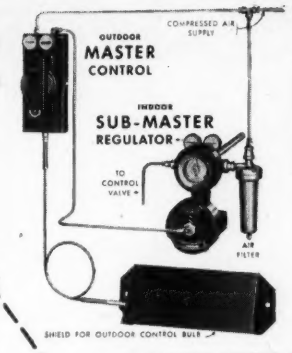

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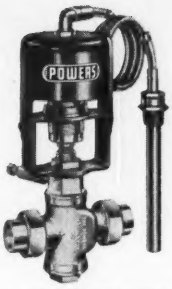

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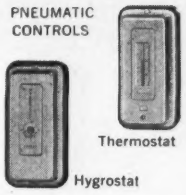

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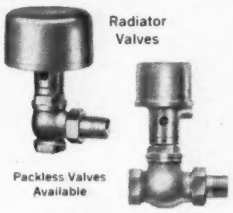

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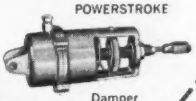

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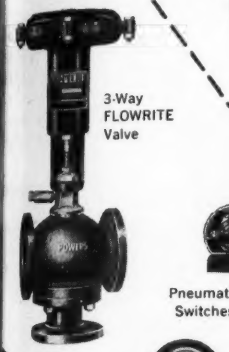

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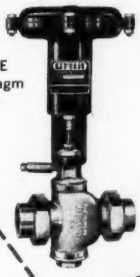

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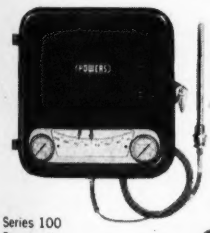

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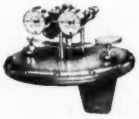

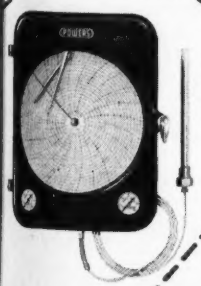

Left: Series 100 Recording Regulator

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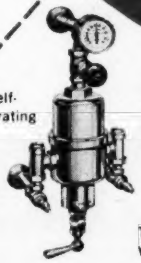

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Houston Exhibit Expanded

FOR THE first time the National Instrument Conference and Exhibit will leave the old and established industrial centers and will take residence during the week of September 10-14, 1951 in a new and rapidly expanding center of industrial activity: Houston, Texas. The foresight of the members of the Houston Section ISA in urging their home city for the 1951 Conference and Exhibit, and that of the Board of Directors in accepting their recommendation, have thus far been amply justified by the excellent response of the instrument industry to the invitation to exhibit.

154 booths were originally laid out in the exhibit hall of the Sam Houston Coliseum and reservations were received for all of these, plus nine additional booths, in the first 60 days of the sale of space to past exhibitors in Buffalo and St. Louis. Fortunately floor area was available in the Coliseum for additional exhibit space, and 61 more booths have been added to the original 154, making a total of 215.

Ten booths have been set aside for the use of the Cooperating Societies and for the Government Agencies, making a total of 193 booths reserved as of April 2, 1951. At no previous time in the history of the National Instrument Conference and Exhibit have so many booths been reserved so far in advance of the actual date of the Instrument Show.

The remaining 22 booths have been placed on general sale and invitations to exhibit were mailed in late February to about 2300 companies who had not participated in the Buffalo (1950), or in the St. Louis (1949), Instrument Exhibit. From the rapidity with which the booths have been moving it is logical to assume that the remaining 22 booths will be reserved in the very near future.

From personal contact and from correspondence with many of the exhibitors, we have learned that they are looking forward to the Houston Exhibit with considerable enthusiasm and are planning their usual all-out effort to provide informative displays of their products. Their well-informed engineers will be on duty in force to explain operations and discuss applications of the many and varied instruments and accessories that will be on display.

Again we wish to remind executives, engineers, and instrument men that the National Instrument Conference and Exhibit offers the ONE great opportunity of the year to learn more of the tools of measurement, control, inspection and testing. A few days spent in listening to the many outstanding speakers at the Conference, in discussion of one's problems with the exhibitors' engineers,

and in trading shop talk with old and new friends will be of greater value to the visitor and to his company than many hours of isolated study.

Following is a list of exhibitors who have reserved exhibit space as of April 2, 1951.

Acragage Co.
Aircraft Marine Products Inc.
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American Machine & Metals Inc., U. S. Gage Div. & Gotham Instrument Div.
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Assembly Products Co.
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Automatic Temperature Control Co., Inc.
Bailey Meter Co.
Baird Associates, Inc.
Baldwin-Lima-Hamilton Corp.
Barton Instrument Corp.
Beckman Instruments Inc.
The Bristol Co.
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Brown Instruments Div., Minneapolis-Honeywell Reg. Co.
The Brush Development Co.
Buffalo Meter Co.
Burgess Battery Co.
Century Geophysical Corp.
Climax Controls Div., Black, Sivalls & Bryson Inc.
Cole Instrument Co.
Conoflow Corp.
Consolidated Engineering Corp.
Continental Equipment Co.
Cook Electric Co.
Crosby Steam Gage & Valve Co.
Daniel Orifice Fitting Co.
Davis Instruments Div., Davis Emergency Equipment Co.
De Zurik Shower Co.
Edin Co., Inc.
Eggelhof Engineers
Electric Auto-Lite Co.
Fenwal Inc.
Fisher Governor Co.
Foxboro Co.
Fulton Sylphon Div., Robertshaw-Fulton Controls Co.
General Electric Co.
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Gulf Coast Spectrographic Society
Hagan Corp.
Hammel-Dahl Co.
Hankison Corp.
The Hays Corp.
Heiland Research Co.
Helicoid Gage Div., Amer. Chain & Cable Co., Inc.
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North American Philips Co.
Palmer Thermometers Inc.
Panellit, Inc.
Penberthy Injector Co.
The Perkin-Elmer Corp.

Continued on page 48

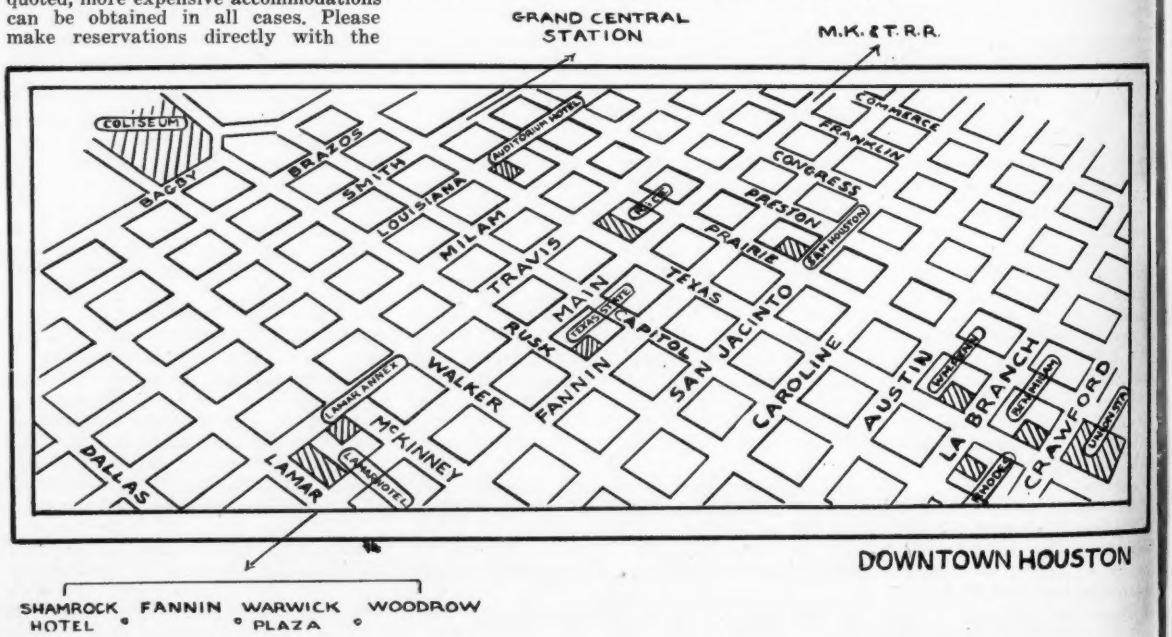
Your Hotel Reservation — Houston

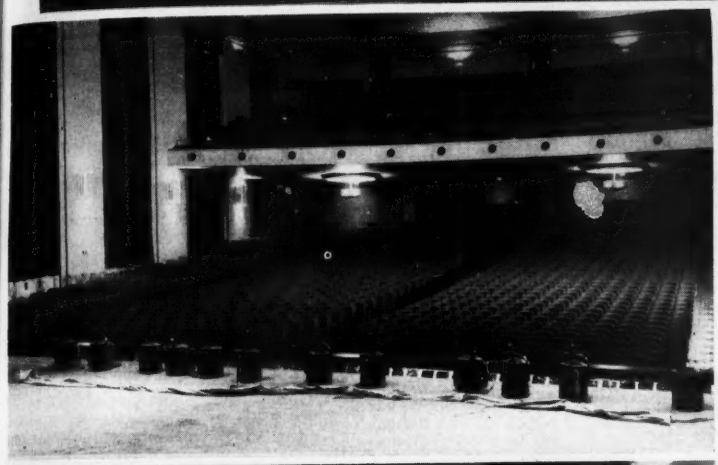
If you plan to attend the Sixth National Instrument Conference and Exhibit in Houston, Texas, from September 10-14, 1951—and have not as yet made your hotel reservations in that city, you are cautioned to proceed to do so without further delay. The room situation will be critical in September, and an early reservation made now will save you considerable time and trouble later on. Those who failed to make early reservations for the Buffalo Show are well aware of the excessively trying annoyance of last minute accommodation making. Do it now and clip the map for future use.

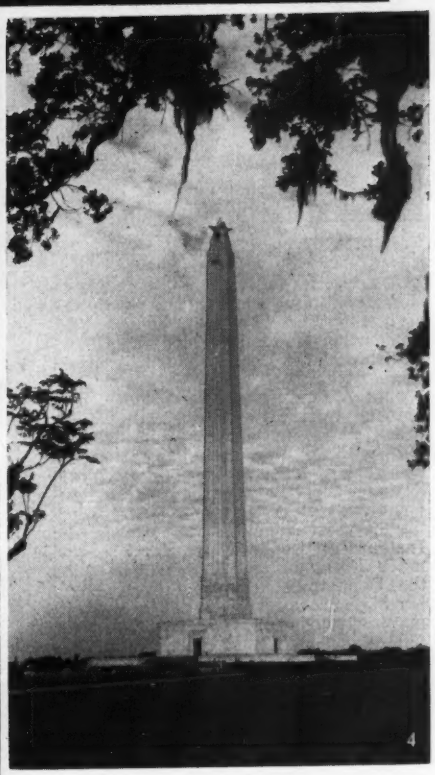
Below is a map of downtown Houston showing the hotels in relation to the Coliseum, at the upper left. Below is a list of the hotels who have committed rooms for the period of the Exhibit. Prices appearing below are the lowest quoted, more expensive accommodations can be obtained in all cases. Please make reservations directly with the hotel of your choice, advising the hotel that you intend to visit the Instrument Conference and Exhibit and stating the approximate date and time of arrival, the number of days accommodations and the type you require.

Hotel	*Street Location*	*From Coliseum*	*Singles*	*Doubles*	*Twins*	*Suites*
Auditorium	Texas & Louisiana	6 Blocks	$2.25	$3.50	$4.50	
Ben Milam	Texas & Crawford	12 Blocks	3.25	4.50	6.00	$14.00
Lamar Hotel	Main & Lamar	7 Blocks	5.00	7.00	8.00	9.00
Lamar Annex	Travis & McKinney	7 Blocks	2.50	3.50	5.00	
Rice	Main & Texas	7 Blocks	5.00	7.00	*	**
Sam Houston	Prairie & San Jacinto	11 Blocks	2.50	3.50	5.00	
Shamrock	Main & Bellaire	5 Miles	6.00	8.00		100.00†
Texas State	Fannin & Rusk	6 Blocks	3.50	5.50	6.00	††
Wm. Penn	Texas & LaBranch	12 Blocks	2.75	3.75	3.75	
Woodrow	1412 Fannin	1 Mile	2.50	3.50		
Fannin	3920 Fannin	2½ Miles				4.00
Rhodes	611 LaBranch	12 Blocks	3.00	3.50	4.00	
Warwick	Main & Herman Drive	3½ Miles	4.00	6.50		9.00
Plaza	5020 Montrose	3½ Miles	4.00	6.00		10.00

*Combination Room: $8.00
**Suites Single: $16.00; Suites Double: $25.00
†Parlor & 1 Bedroom: $25.00; Parlor & 2 Bedrooms: $30.00
††Parlors: $9.50; Suites Single: $16.00; Suites Double $20.00







HOUSTON, TEXAS

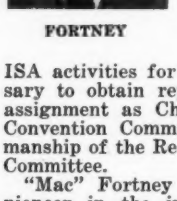
Scene of 6th National Instrument Conference and Exhibit September 10-14, 1951

1. Sam Houston Coliseum and Music Hall where exhibit & conference will be held.
2. Inside the Music Hall.
3. Coliseum's "Corral Club."
4. The San Jacinta Monument.
5. "Chuck Wagon" and Meeker Plantation, site of Wednesday night social and entertainment program.

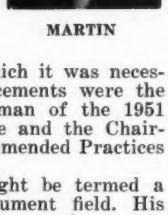
J. R. Martin Replaces Fortney as Houston Conference Committee Chairman

Due to a recent change in position at Humble Oil's Baytown Plant which involved assuming broader responsibilities, W. H. (Mac) Fortney, one of the ISA "work horses" has had to indefinitely discontinue his activities in ISA and other similar organizations. In a recent Executive Training Program assignment, Fortney was assigned to the job of Assistant Superintendent of Maintenance and Construction.

Since on this job he will be concerned with many activities other than with the instrument field, and since it will require his full time, it is necessary that he discontinue outside activities in the instrument field. The two major



FORTNEY



MARTIN

ISA activities for which it was necessary to obtain replacements were the assignment as Chairman of the 1951 Convention Committee and the Chairmanship of the Recommended Practices Committee.

"Mac" Fortney might be termed a pioneer in the instrument field. His first job in instrument work was in 1923 with the Texas Company. He went to the Humble Company in 1927 and has been directly concerned with instrument work since that time. After serving in various mechanical jobs in the Instrument Department, Fortney was made Foreman in 1937. At that time the Department consisted of 35 men. During subsequent years it grew to a maximum of nearly 200 men.

Fortney participated in the organizational meeting of the Houston Instrument Society, held in December, 1945, and was subsequently elected to serve as its first President. He has been active in this organization's work ever since, while it was still the Houston Instrument Society, and since it has become the Houston Section of ISA.

Fortney served as a member of the Steering Committee which organized the Texas A & M Symposium on Instrumentation for the Process Industries, and served on this Committee from 1946 through 1950. While serving on this Steering Committee he functioned in the following capacities: presided over meeting Sept., 1946; on panel discussion, 1947; Director of Publicity, 1947; Exhibits Chairman, 1948 and 1949; presented paper, "Organization of an Instrument Department", 1949; Technical session chairman, 1950.

Fortney has presented several papers before ISA groups; the first paper being "Instrument Maintenance Facilities" before the New Jersey Section of ISA in December, 1946. He presented a paper at the ISA Spring Meeting in Cleveland entitled, "Gadgets, Gimmicks, and Ways Out". At the annual meeting, September, 1947 in Chicago, he presented a paper entitled, "Application of Conventional Industrial Instruments to Power Plant Control".

In addition he has authored a number of papers, among which are: "Field Heat Treating of Refinery Piping", *Petroleum Refiner*, May, 1946; "Maintenance and Repair of Refinery Control Valves" co-authored with Clyde Pryor for *Petroleum Refiner;* "Instrument Maintenance for Continuous Process Plants", *Southern Power and Industry*, May, 1948; Introduction to Instrumentation and Control Section of the "Better Production" issue of *Southern Power and Industry*, October, 1948; and "How We Use Industrial Process Instruments in Power Plant Control", *Power Generation*, August, 1949.

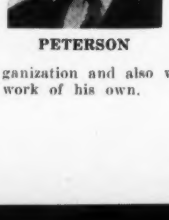
Fortney was a charter member of the ISA Recommended Practices Committee, having attended its first meeting in Cleveland in the Spring of 1947. At that time he was appointed Chairman and asked to organize the Subcommittee on "Recommended Practices for Control Valve and By-Pass Installations". He served as Chairman of this Sub-committee until the Spring of 1949 when he succeeded Jim Kerley, the second Chairman of RPC.

In the Fall of 1948 Fortney was appointed Chairman of a Committee to investigate the possibility of inviting the ISA to hold its annual Conference and Exhibit in Houston in 1951. At the Toronto meeting in 1949, while acting as Director from the Houston Section he obtained official endorsement and approval of Houston as the 1951 meeting site. After this he was asked by the Houston Section to head the permanent 1951 Convention Committee.

Since that time, he and his committee have been working with the Society Executive Secretary on plans and preparations for the 1951 Conference and Exhibit. Fortney was designated as Chairman of the Meetings Committee for the year 1950-51.

In these latter assignments Fortney has been succeeded by J. R. Martin, who also succeeded him in his job as general Foreman of the Instrument Department at Humble's Baytown Refinery. Martin is also a Charter member of the Houston Instrument Society, and has also been active in it since its conception. Martin has served on the Houston Section Board of Directors during the past year and has also been active in other outside instrument work. While not the pioneer in the instrument field that Fortney is, Martin promises to be his equal as a "work horse" in ISA.

Peterson Appointed Instrumentation Head



PETERSON

Dr. Edward R. Weidlein, Director, Mellon Institute, Pittsburgh, Pa., has announced the appointment of Axel H. Peterson, a specialist in scientific instruments, as Head of that Institute's new Department of Instrumentation. In that position Mr. Peterson, a member of the ISA, will serve as an expert adviser to members of the research staff of the organization and also will conduct investigational work of his own.

"Postmark Advertising" for Houston

This year several innovations will be made in attendance promotion at the Sixth National Instrument Conference and Exhibit, Houston, September 10-14. One of these is illustrated here.

If your company has a Pitney-Bowes Machine in its mail room you are urged to approach the proper person in charge and determine if they are willing to insert the above illustrated "Postmark Advertising" for use in their machine. If they are willing to do this, please advise the National Office, 921 Ridge Avenue, Pittsburgh 12, Pa. giving the model number of the machine. The ISA National Office will then have a "slug" made and ship it to you. Your early attention to this will be appreciated.

Letter to the Membership

As the representative of every member and of every Section on the Executive Committee of the Society, I should like to review briefly the Committee activities of the Membership Relations Division which should be of interest to all.

The Society needs a brief history of its first five years, a history that can be given to prospective members as well as all present members. We are looking towards the completion of this history during this calendar year. We can take pride in the first five years, for the growth has been vigorous, and the Society is actually quite mature for its few years of existence.

Many of you, I am sure, realize that the instrument manufacturers provide much of the personnel that is active in the Society. These "peddlers" are officers, committee chairmen, and committee members, both locally and nationally. The manufacturers also provide speakers and provide exhibits, both locally and nationally. Granted, that we who are cutomers pay the bill for this; but we still should realize that there is a close and continuing relationship between the Society and the manufacturers group. That is the reason why there is an Instrument Manufacturers Committee which has been called upon to review a number of the Society operations which directly affect the instrument manufacturer. We do not want the Society operations to be a burden on any specific group of individuals or companies.

The story of the Employment Committee was told in the January issue of the Journal. It was so ably presented that there is no need for elaboration on the subject. Suffice it to say that the members of this Committee are anxious to help members and non-members in instrument employment activities. Please use them when you can.

We, like all other important organizations, are represented in Washington. Our National Defense Committee considers one of its prime jobs that of defining the activities and the importance of the instrument technician and the instrument engineer to government authorities. Key people in the United States Government have been taken to industrial plants by National Defense Committee members to learn what instrumentation does, and why the people associated with it are of prime importance in the mobilization effort.

Because instrumentation is as broad as science or engineering itself, we find many Societies to some degree being involved in instrumentation. For that reason, we have a Coordinating Committee whose job it is to provide top-level liaison with AIEE, ASME, API, ASA, AIChE, ASRE, and many others. The Committee helps to coordinate some activities and prevent duplication in others. Locally, the Committee's existence is reflected by the joint meetings of ISA and other Societies held by the local Sections. Those without some joint meetings are foolish, for larger attendance can command better speakers and give opportunity to meet more prospective members. Why doesn't every Section aim at two joint meetings with other Societies during 1951?

One of the work-horses of the Society is the Sections and Membership Committee, whose members are experienced in local Section and society activities. They have no authority over Sections; their suggestions, however, are generally put into affect because of a Section's respect for the Sections Committee member's judgement. The Committee's job is to sample the opinion of members of the Society and to guide the Executive Committee on matters which directly affect the individual member.

The Sections Committee has set up individual membership quotas for the Sections this year. The quota totals 5000. It is certainly conservative, for an instrument society of only 5,000 members includes only a small portion of those people actively interested in instrumentation in this country.

The Sections Committee has long promoted the idea of technical committees within the local sections. This is tied in with our slogan for the Sections of "Know your membership better." If your Section does not have technical committees, we suspect it is not always because there is no need, but because you have not investigated the instrument potential of your area, and found that your potential and existing membership requires the technical committee structure. It is certainly logical to consider that the establishment of technical committees within the Sections will increase the membership. There may be more programs per year, and there is obviously additional work for the officers, though it need not be appreciable. Increasing strength of the Society goes hand in hand with increasing membership. Greater strength will come, if the Sections are willing to take on a little additional work. The Sections can make us nationally strong or weak. Let's get musclebound!

There are not enough individual members who are putting their "two cent's worth" into the National Society. We always want ideas, suggestions, and criticisms. Speak up! Let us have them! With them, we can make this Society not a better one, but the best one going.

NELSON GILDERSLEEVE, V. P.
Membership Relations Division

EXHIBITORS *Continued from page 462*

Proportioneers, Inc.
Radio Corp. of America
The Refinery Supply Co.
Republic Flow Meters Co.
Research Control Instrument Co.
Robinson Orifice Fitting Co.
Rockwell Manufacturing Co.
Milton Roy Co.
R-S Products Co.
Ruska Instrument Co.
Sarco, Co., Inc.
Servo Corp. of America
Southwestern Industrial Electronics Co.
Streeter Amet Co.
Superior Electric Co.
Surprenant Mfg. Co.
The Swarthwout Co.
Taylor Instrument Cos.
Telechron, Inc.
Texas A & M College
H. O. Trerice Co.
Trinity Equipment Corp.
Vapor Recovery Systems Co.
Veeder-Root, Inc.
Wallace & Tiernan Products Co., Inc.
The Weatherhead Co.
W. M. Welch Mfg. Co.
Weston Electrical Inst. Corp.
Wheelco Instruments Co.

National Committee Membership

SPECIAL COMMITTEES

Society Structure and Planning Committee: A. H. Shafer, Chairman, (Pgh), Foxboro Co., 5151 Baum Blvd., Pgh. 24, Pa.; L. M. Susany, Sec'y., (Pgh), Carnegie Institute, 4400 Forbes St., Pgh. Pa.; R. D. Webb, (Char), Carbide & Carbon Chem. Corp., S. Charleston 3, W. Va.; E. G. Bailey, (Phila), Bailey Meter Co., 85 Liberty St., N. Y. 6, N. Y.; A. E. Tarr, (Phila), Leeds & Northrup Co., 4901 Stenton Ave., Phila. 44, Pa.; J. J. Grebe, (D), Dow Chem. Co., Midland, Mich.; C. H. Colvin, (N Y), G. M. Giannini & Co., 697 Morris Turnpike, Springfield, N. J.; G. F. Akins, (R), 107 Pomona Dr., Rochester 12, N. Y.; W. G. Brombacher, (Wash), Nat'l. Bureau of Stds., Washington 25, D.C.; R. J. S. Pigott, (Pgh), Gulf Res. & Dev. Co., P.O. Box 2038, Pgh. 30, Pa.; P. T. Sprague, (Chi), Hays Corp., 704 E. 8th St., Michigan City, Ind.

Nominating Committee: M. S. Jacobs, Chairman, (Pgh), M. S. Jacobs & Assoc. 807 Bessemer Bldg., Pgh. 22, Pa.; G. N. Ehly, (Phila), 180 Ashland Ave., W. Manayunk, Phila., Pa.; A. P. Harmon, (R), 333 Augustine St., Rochester 13, N. Y.; W. H. Brand, 104 Mayfair Lane, Oak Ridge, Tenn.; J. A. Ford, (Bos), Jerguson Gage & Valve Co., 87 Fellsway St., Somerville, Mass.; M. J. Johnson, (Louis), 6502 Southside Dr., Louisville, Ky.; A. V. Novak, (GC), E. I. duPont de Nemours & Co., Orange, Texas; J. W. Huether, (Ont), 311 Southerland Dr., Leaside, Ont., Canada; P. R. Hoyt, (N Calif), Shell Dev. Co., Emeryville, Calif.; J. M. Ribble, (T), Phillips Petroleum Co., Bartlesville, Okla.; J. R. Shaffer, (Cent Ill), Corn Products Ref. Co., Pekin, Ill.; R. Lehman, Pure Oil Co., Toledo 1, Ohio.

Special Committee for Abstracting Service: G. F. Gardner, Chairman, (E NY), Gen. Eng'r. & Con. Lab., G. E. Co., 1 River Rd., Schenectady 5, N. Y.; J. Johnston, Jr., (Wil), Shellburne Dr., Shellburne, Wilmington, Del.; H. C. Givens, (S Texas), P.O. Box 637, Falfurrias, Texas; R. A. Ackley, (Calif), 328 Highland St., Fletcher Hills, El Cajon, Calif.; Prof. H. C. Roberts, U. of Illinois, 205 Talbot Lab., Urbana, Ill.

Special Manpower Classification Committee: To be appointed.

MEMBERSHIP RELATIONS DIVISION

Coordinating Committee: E. S. Lee, Chairman, (E N Y), 1350 Wendell Ave., Schenectady 8, N. Y.; C. O. Fairchild, (N Y), Chain Bridge Rd., R.F.D. #3, Fairfax, Va.; R. L. Goetzenberger, (Wash), 714 Norway Dr., Chevy Chase 15, Md.

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Creek, Mich.; R. W. Lutz, (Rich), 1735 Davison St., Richland, Wash.; J. S. Stenehjem, (Twin Cities), Bristol Co., Rm. 201 225 S. 5th St., Minneapolis 2, Minn.; L. G. White, (Wash), Day & White, 718 Mills Bldg., Washington, D. C.; T. M. Laurenson, (Wayne Co), 3649 19th St., Wyandotte, Mich.

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Committee on Instrumentation for Production Processes: D. M. Boyd, Jr., Chairman (Chi), Universal Oil Prod. Co., 310 S. Mich. Ave., Chicago 4, Ill.; F. H. Trapnell, (Wil), E. I. DuPont De Nemours & Co., Wilmington 98, Del.; C. E. Bragg, (Chi), Std. Oil Co. (Ind), 200 N. Y. Ave., Whiting, Ind.; W. H. Brand, (OR), Oak Ridge Nat'l Lab., P.O. Box P., Oak Ridge, Tenn.; R. Pond, (R), Taylor Inst. Cos., Box 110, Rochester 1, N. Y.; C. Clementson, (Rich), Hanford Eng'r. Wks., Richland, Wash.; C. A. Hansen, Jr., (ENY), Knolls Atomic Power Lab., Schenectady, N. Y.; J. T. Simmons, (Chi), Box 1663, Los Alamos, N. Mex.; P. R. Hoyt, (N Cal), Shell Dev. Co., Emeryville, Calif.; R. N. Wilson, (Cum), Kelly Springfield Tire Co., Cumberland, Md.; J. W. Percy, (NJ), U. S. Steel Co., Kearney, N. J.; E. S. Mehnert, (NJ), Rose City Gds., Apt. 62, 17-33 Madison Ave., Madison, N. J.; E. H. C. Brown, (Louis), Seagram & Son Inc., 7th St. Rd., Louisville, Ky.; F. R. Bridges, Post Cereal Div., Gen. Foods Corp., Battle Creek, Mich.

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Instrument Maintenance & Operation Committee: J. Johnson, Jr., Chairman, (Chi), E. I. duPont de Nemours & Co., Wilmington, Del.; A. K. Joecks, (NY), 81 Grove Ave., Glen Rock, N. J.; G. A. Larsen, 612 11st St., Lockport, Ill.; R. L. Nichols, (GC), 715 Madison St., Beaumont, Texas.

Instrument Calibrating Techniques Sub-Committee: A. K. Joecks, Chairman, (NY), Consolidated Edison Co., 708 1st Ave., N. Y. 17, N. Y.; G. A. Pettit, P.O. Box 96, St. Louis, Mich.

Instrument Installation Practices Sub-Committee: H. A. Hulsberg, Chairman, (Chi), Universal Oil Prod. Co., 310 S. Mich. Ave., Chicago 4, Ill.

Instrument Maintenance Practices Sub-Committee: H. A. Hulsberg, Chairman, (Chi), Universal Oil Prod. Co., 310 S. Mich. Ave., Chicago 4, Ill.; F. Appel, Jr., (Akron), 932 Columbia Ct., Barberton, Ohio.

Instrument Mechanic Training Sub-Committee: G. A. Larsen, Chairman, 612 11th St., Lockport, Ill.; C. W. Braswell, Monsanto Chem. Co., Texas City, Texas; R. H. Briggs, Dow Chem. Co., Midland, Mich.; J. H. Cuthbert, (Chi), Carnegie-Illinois Steel Corp., 3426 E. 89th St., Chicago, Ill.; G. N. Ehly, (Phila), 180 Ashland Ave., W. Manayunk, Phila. 27, Pa.; J. N. Franklin, (Sarnia), Newfoundland Pulp & Paper Mills, Corner Brook, Newfoundland; K. Goldring, (Sarnia), Polymer Corp., Sarnia, Ont., Canada; M. B. Hall, Foxboro Co., Foxboro, Mass.; R. Johnston, Ind. Training Inst., 2150 Lawrence Ave., Chicago, Ill.; M. Ladden, Brown Inst. Co., Phila., Pa.; R. L. Nichols, (GC), Magnolia Petroleum Co., Beaumont, Texas.

Instrument Shop Layouts and Shop Equipment Sub-Committee: R. L. Nichols, Chairman, (GC), Magnolia Petroleum Co., Beaumont, Texas; W. G. Baker, Jr., (Tenn), American Enka Corp., Lowland, Tenn.; A. Keeler, Socony Vacuum Oil Co., Paulsboro, N. J.; A. V. Novak, (GC), E. I. duPont de Nemours Co., Orange, Texas; T. H. Pierson, (S Texas), Corn Prod. Ref. Co., Corpus Christi, Texas; C. E. Werstler, (St Louis), Socony-Vacuum Oil Co., S. 20th St., E. St. Louis, Ill.

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Instrumentation for Transportation Committee: F. H. Catlin, Chairman, (Pres Isle), 216 E. 33rd St., Erie, Pa.; J. J. MacDonald, Pullman Std. Car Mfg.

Co., 1414 Field St., Hammond, Ind.; R. A. Schoenfeld, (Chi), Wheelco Insts. Co., 1200 N. Ashland Ave., Chicago 22.

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Continuous Measurement of Vapor Pressures of Petroleum Products

By ROBERT B. JACOBS*

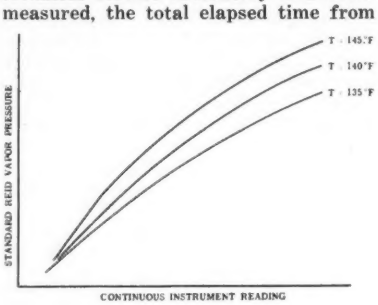
Abstract. Vapor pressure is one of the most important properties of a petroleum product. In gasolines, for example, easy starting and absence of vapor lock depend upon accurate control of the gasoline vapor pressure. In modern refineries, controlled vapor pressure is attained by blending different stocks together. This blending is greatly facilitated by automatic monitoring of vapor pressure by a newly developed instrument. The design and operation of this instrument is explained.

In the refining of petroleum, the fact that different constituents have different vapor pressures is utilized extensively in separating crude into different fractions. Accordingly, one obtains a range of products, from the butanes through the gasoline stocks and heating oils all the way down to the asphalt, separated on the basis of relative volatility. For the purpose of operating a still, an accurate knowledge of volatility is generally not required and still operations are usually based on temperature. However, when stocks are reblended to build up specific products, such as gasoline, an accurate knowledge of vapor pressure is most essential.

In the particular case of gasoline blending, the industry has found that according to the season of the year, a certain volatility is required: too high a volatility can lead to vapor lock, and too low a volatility makes for hard starting. Also, the different market values of the stocks which make up the gasoline naturally place a premium on accurate blending which achieves the correct volatility, at the same time utilizing the different constituents most economically.

The traditional method of measuring vapor pressure of petroleum products is the so-called *Standard Reid Test* as described in the ASTM code. This is a time-tested laboratory method which, for maximum accuracy requires very careful sampling and refrigeration of samples for storage. The Standard Reid Test gives reliable results if the procedure is carefully followed and the Reid bomb and gage are constantly checked. However, serious errors will result if the testing procedure is not adhered to, or if the bomb is not in first-class condition. The actual manipulation time for a Standard Reid Test is approximately 15 minutes per sample, but the elapsed testing time, including chilling time, generally amounts to several hours.

In the usual case, where samples are drawn by operators, delivered to a technical service laboratory and there measured, the total elapsed time from the drawing of the sample to the reporting back by the laboratory generally is of the order of four hours. Naturally, in operations where large quantities of materials are handled, the difference between control based on up-to-the-minute information and that based on information which is four hours late is considerable, both in quality of product and in economy of operations. With the general objective in mind of furnishing (1) continuous indications of the vapor pressure and (2) automatic operation, a new type of instrument* has been developed. Its description furnishes the basis for this paper.



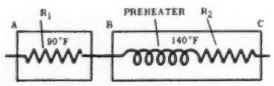


Fig. 1. Pressure drop (across BC). Constant pressure at A (schematic).

Principle of Operation

Referring to Fig. 1, the basic principle of operation of the capillary instrument is explained. Two thermostatted chambers are shown, one held at 90 F., for example, and one at a higher temperature. In the first chamber, a capillary resistance is shown and in the second, a preheater coil and a resistance. Now, if gasolines of different vapor pressures are fed into this resistance combination (the pressure at point *A* being held constant and the pressure at point *B* being observed), the type of curves in Fig. 1 results. As indicated, the slope of the curve may be altered by changing the temperature of the warmer bath.

The explanation for the observed behavior is as follows: The more volatile the gasoline, the greater the amount of boiling which will take place in the hotter capillary. No boiling occurs in the 90-F. capillary. Now, the volume

*In accordance with the long established policy of Standard Oil Company (Indiana) of making its new developments generally available, arrangements have been consummated for the licensing of the Precision Scientific Company, 3737 West Cortland Street, Chicago 47, Illinois, to manufacture and sell this instrument.

THE AUTHOR

Robert B. Jacobs received his BS and PhD degree from California Institute of Technology. He was a National Research Fellow and Instructor at Harvard, and a Lalor Research Fellow and Research Associate at Massachusetts Institute of Technology. He has held the position of Assistant Executive Secretary of the National Research Council, and has worked as a physicist for the M. W. Kellogg Co., and for Distillation Products, Inc. During the war he was in charge of Vacuum Engineering and Development at K-25 (Gaseous Diffusion) Plant at Oak Ridge, Tenn. He is presently Associate Director, Engineering Research Dep't, Standard Oil Company (Indiana).

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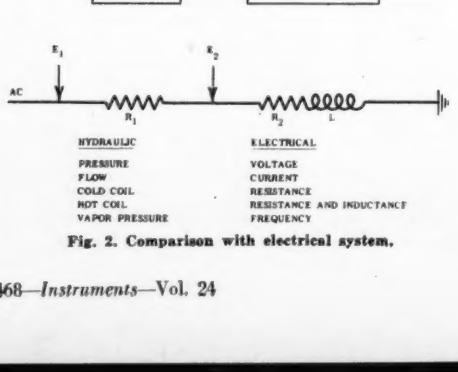


Fig. 2. Comparison with electrical system.

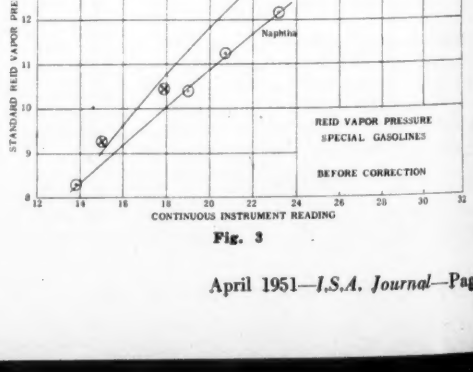


Fig. 3

occupied by a given quantity of liquid gasoline plus its vapor depends upon the amount of boiling which takes place, and the greater this volume the greater the resistance to flow for a given quantity of gasoline. Accordingly, R_2 will increase as volatility increases while R_1 remains substantially constant, and the

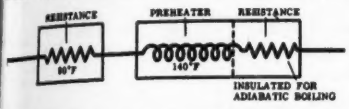


Fig. 4. Schematic showing principle of automatic compensation for gasoline composition.

percentage of the total pressure drop which takes place across R_2 will be a function of the gasoline volatility.

An electrical analog of this principle is given in Fig. 2. The essential feature of this analog is that the second (hotter) resistance is equivalent electrically to an inductive element. Accordingly there exists a correspondence between *vapor pressure* in the hydraulic system and *frequency* in the electric system. Thus it can be seen, if an a-c. current is fed in the electric network at E_1, the voltage E_2 will measure the frequency of the a-c. supply. In the hydraulic case, P_2 (corresponding to E_2) will measure vapor pressure (corresponding to frequency).

Use with Gasolines of Variable Compositions

The system shown thus far is adequate for relatively pure or close-boiling mixtures but does not take into account the fact that gasoline compositions are variable over a certain range. For the purpose of simplification, assume that there are two types of gasoline containing maximum and minimum amounts of butane. These will be referred to respectively, as high butane (or butane) and low butane (or naphtha) gasolines.

Now, if one employs a set-up such as that shown in Fig. 1 and runs both high butane and low butane gasolines of the same Reid vapor pressure, curves similar to those shown in Fig. 3 are obtained. For two such gasolines, it has been found that the amount of boiling which occurs in the second capillary is greater for the low butane gasoline if the capillary is maintained under isothermal conditions. Accordingly, other qualities being equal, the increase in its resistance to flow through R_2 (Fig. 1) is greater for the low butane gasoline. This is indicated in Fig. 3, which shows two curves for gasoline blends held within specifications, but with maximum and minimum allowable butane contents.

To compensate for these differences with gasoline, the principle illustrated in Fig. 4 has been devised. The second resistance is removed from the higher temperature bath and placed in an insulated compartment so that boiling which occurs in this resistance takes place under approximately adiabatic conditions. The objective here is to utilize the fact that the low butane gasoline has a greater amount of latent heat associated with its boiling than does an equivalent high butane gasoline. Accordingly, a low butane gasoline is cooled more by adiabatic boiling than is the equivalent high butane gasoline.

This differential cooling by adiabatic boiling has been found to provide the exact type of compensation desired. In Fig. 5, results are shown for a number of runs on special gasolines on a machine employing this principle. It is seen that the compensation is adequate. Fig. 6 shows the results of a number of measurements made with this machine under plant blending conditions. Where two points are shown on the same vertical line, the two standard Reid determinations on the same material gave results which differed significantly, and two values have been indicated.

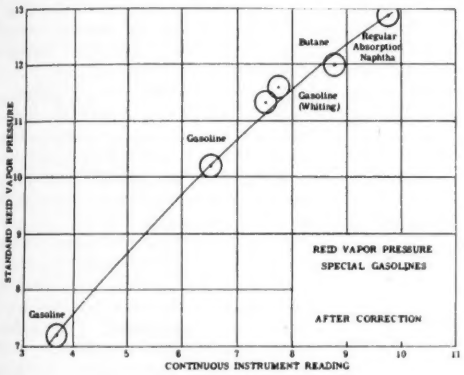


Fig. 5

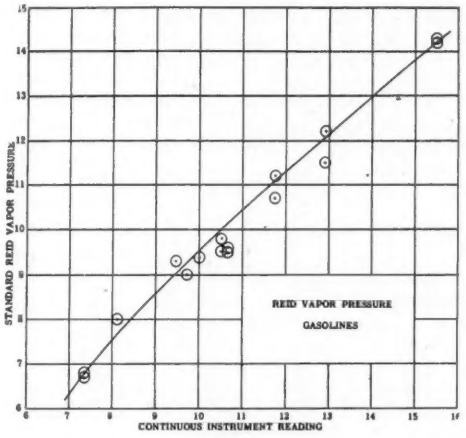


Fig. 6

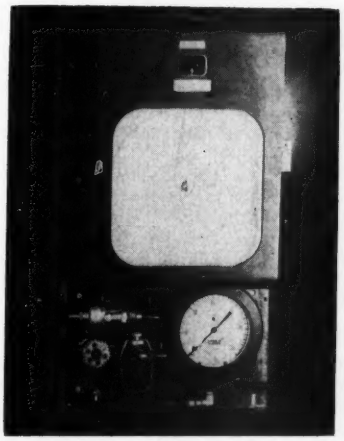


Fig. 7

The first machine used in blending operations is shown in Fig. 7. The pressure recorder, being the largest piece of equipment, dictated the size of the installation. One item of major concern has been the long-term accuracy of the capillary type of system since it was anticipated that some gumming would take place over a period of time in the fine capillaries employed, and this would result in a change in calibration.

Fig. 8 indicates the extent of the change which takes place in continuous operation and shows that gumming need not impair the accuracy of the installation if a regular program of flushing with a suitable solvent is employed. In the time interval covered here, appreciable gumming took place only after several months had elapsed without flushing. As is indicated, the calibration was checked at periodic intervals with pure cyclopentane, which stores without change in vapor pressure due to weathering and is accordingly easier to handle than a gasoline standard.

Summary

By way of summary, Tables I and II are given. Table I gives some typical operating data for the continuous type instrument. The range of operation shown is the most useful for our purpose. It is emphasized, however, that

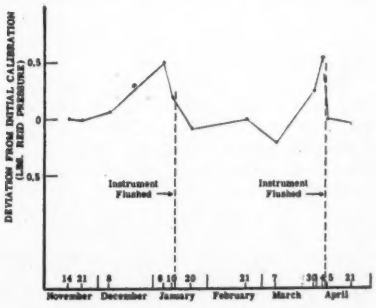


Fig. 8. Whiting Installation. Automatic continuous Reid vapor pressure instrument test readings on cyclopentane.

TABLE I—Typical Specifications for Continuous Instrument

Feed rate	1 - 2 gals. per hour
Feed pressure	30 psig.
Outlet pressure	Atmospheric
Temperatures	Bath (1): 90 F. Bath (2): 140 F.
Recorder range	5 psig.—20 psig.
Vapor pressure range	5 psi.—15 psi. rvp.

TABLE II—Operating Characteristics

Method	*Continuous*	*Standard Reid*
Type	Secondary	Primary
Sources of error	(1) Fouling of Capillary (2) Air bubbles in feed	(1) Faulty handling of sample (2) Faulty manipulation of test (3) Leaks in equipment
Precision	± 0.1 psi.	± 0.1 psi. + 1% rvp. (with expert operators)
Advantages	(1) Rapid responding (2) Simplicity, continuous reading	A primary type of test
Disadvantages	(1) Requires a clean bubble-free feed	(1) Not continuous (2) Time consuming (3) Skillful handling required

wide variations in operating range are possible by changing temperatures, recorder ranges, etc. Table II summarizes the operations of the continuous type of instrument as compared to the Standard Reid method.

While capillary fouling and air bubbles in the feed have been listed as possible sources of error in the continuous method, they are by no means inevitable. The purpose of listing them has been more to indicate that precautions for their elimination must be taken. At present, it is believed that a maintenance schedule of flushing followed by calibration check with a pure hydrocarbon once a week is adequate. This operation requires about one and one-half hours. Then, if feed pressure is accurately controlled at all times, the accuracy of the readings obtainable is at least as good as a Standard Reid Test carefully executed, and certainly better than any Reid Test where shortcuts are taken.

A Non-mathematical Discussion of Flow Measurement

By J. B. McMAHON*

The effect of the drop in pressure caused by the restriction of flow in a pipe has been used as a measurement of fluid flow almost from time immemorial. Orifices were used by the Chaldeans in Asia Minor and by the Maya Indians in Southern and Central Mexico as the basis for accurately measuring time for astronomical calculations; and the ancient Romans used orifices as meters for water. In ancient Rome, an orifice was part of a plug cock in the water supply line to a house, which was turned on for a certain number of hours each day, and the householder charged accordingly. The Romans must have been well acquainted with the laws or fluid flow through orifices, for there was a specification limiting the ratio of orifice size to line size.

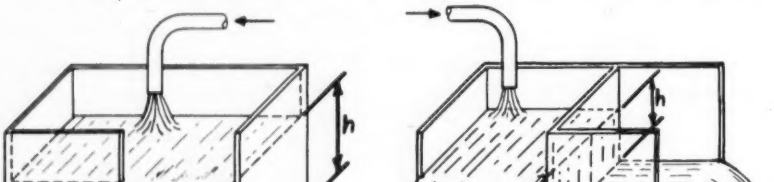


Fig. 1

The first definitive work on such devices probably was done by Poncelet and Lesbros in 1827 to 1835; in 1885, Hamilton Smith published orifice coefficients for water which were checked in 1940 and found to be within 1/3 of 1 percent; the description and theory of the Venturi tube were published by Clemens Herschel in the transactions of the American Society of Civil Engineers in 1887. This device Herschel named after Venturi, who observed the principle in 1791.

It is not known definitely who first used the orifice plate for gas flow measurement, but it was probably before 1890, since orifice meters were used in the vicinity of Columbus, Ohio at that time for measuring natural gas. These had been installed at the suggestion of Professor E. W. Robinson of Ohio State University. About 1904 T. R. Weymouth installed an orifice in a flange union in series with a pitot tube in order to determine the characteristics of orifice plates. This work was not completed until 1911. In the interim John E. Hodgson of England visited Mr. Weymouth and exchanged experiences with him. It is of interest that their conclusions, on work done independently at widely separated locations, were quite similar.

Since then, numerous independent investigators and several joint committees have studied the problem of the use of head meters. The American Society of Mechanical Engineers formed a committee to study the subject in 1915, which later became the ASME Special Research Committee on Fluid Meters. During the early years of its existance, this committee did very little direct research, but devoted its efforts to correlating and coordinating the work done by other investigators.

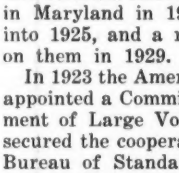
In 1919 the National Bureau of Standards was requested by the U. S. Fuel Administration to investigate this subject, and as a result of this and other similar requests, started an extensive series of tests at Edgewood Arsenal in Maryland in 1922. These extended into 1925, and a report was published on them in 1929.

In 1923 the American Gas Association appointed a Committee on the Measurement of Large Volumes of Gas, which secured the cooperation of the National Bureau of Standards. This committee conducted extensive tests in Chicago, using a large holder as a reference.

In 1924 the Natural Gas Association, now the Natural Gas Department of the American Gas Association, established a Gas Measurement Committee, which started work in 1925 that extended over several years. In 1927 this committee issued a preliminary report recommending installation requirements for orifice meters.

The Author

Graduated in 1921 from Carnegie Institute of Technology, Jerome B. McMahon served for two years in the Sales Engineering department of The National Supply Company, Tulsa, and then for 18 years was with The Foxboro Company as sales engineer, division manager, assistant general sales manager, and manager of the Controller division. Since 1941, he has been application engineer and manager of sales promotion for Republic Flow Meters Company, Chicago. McMahon is the author of the section on automatic control in the fourth edition of Mark's Mechanical Engineers' Handbook. He is the 1951 President of the ISA and has been a member of ASME Committee on Automatic Control Terminology since its inception.



*Republic Flow Meters Co., Chicago, Ill.

NOTE: Presented before the Fifth Annual Convention of the Instrument Society of America, at Buffalo, N. Y., Sept. 12-18, 1950.

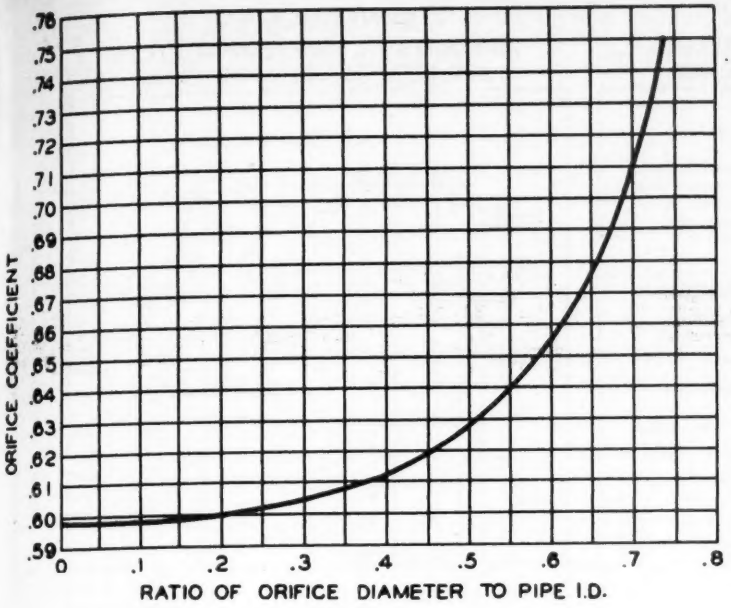


Fig. 2

In 1931, a joint committee of the American Society of Mechanical Engineers and the American Gas Association was formed, to correlate the work done up until them, and particularly to take advantage of the large amount of work previously financed by the AGA; to pursue the investigations into the theory and application of flow meters; and secure the endorsement of the National Bureau of Standards as essential to proper establishment of a national standard.

As a result of all this work, an extensive series of tests was run in 1932-1933 at the hydraulic laboratory of Ohio State University at Columbus, Ohio. These are referred to as the Columbus tests, and are considered by the joint ASME-AGA committee to be the most extensive and reliable ever run. They are the basis for the present coefficients as presented in the joint ASME-AGA committee report, and incorporated in the ASME research publications—"Fluid Meters—Their Theory and Application."

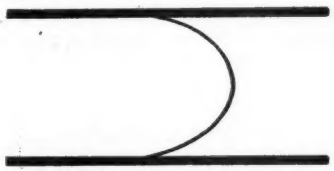
The data from the Columbus tests, and other later tests sponsored by the committee, were submitted to the Bureau of Standards for analysis and a report on this analysis was approved by the Director of the Bureau in May, 1934. This analysis does not cover the full range of possible operating condition, but does provide a satisfactory basis for commercial application.

In addition to all this work in this country, similar investigations were pursued abroad, principally in England and Germany. The results corroborated the work done here.

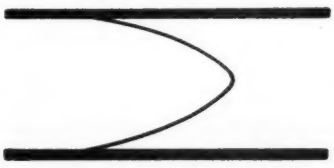
Fundamental Principles Involved

It seems, then, that a tremendous amount of effort has been expended in verifying the truth of a very simple principle, which is that the total energy in a flowing stream of fluid remains constant. Therefore if the velocity is increased, thereby increasing the kinetic energy, it must be at the cost of potential energy, and result in decreased pressure.

It would hardly seem that such an apparently simple problem would require all this amount of authority and investigation, if it were quite that simple. There must be more to it than appears from this simple statement, and perusal of the papers and handbooks on the subject bears this out, for the equations and their derivation are apparently very complex and confusing. It is the purpose of this paper to show that the underlying concept is still a very simple one, and that all the arithmetic involved is necessary largely on account of operating conditions, commercial practice, and for convenience.



TYPICAL VELOCITY DISTRIBUTION IN TURBULENT FLOW



TYPICAL VELOCITY DISTRIBUTION IN LAMINAR FLOW

Fig. 3

The factors which must be incorporated have been reduced to tabular form, and many of them are included in the equations so that they will not be neglected in the exceptional case where they are needed. For the ordinary installation the calculations could be much simpler than the equations ordinarily used would indicate.

Referring to the left-hand diagram of Fig. 1, consider a tank which is kept at a constant level. If the liquid in it is allowed to escape through a hole in the bottom, it will be found that the velocity of the issuing stream is the same as would be the velocity of liquid spilling over the edge of the tank, upon reaching the same elevation as the hole. Also, as shown in the right-hand view of Fig. 1, if two abutting compartments of a tank are maintained at constant, but different levels, the velocity of liquid through a hole connecting them will be found to be the same as would be the velocity of liquid falling from the higher to the lower level, just at the elevation of the lower level.

This same principle applies regardless of the type of fluid—whether it is liquid, vapor, or gas, within very wide limits. In the case of vapors and gases, it is necessary to restrict the ratio of the head loss to the total head, for thermodynamic reasons, but generally speaking if this is done, the hydraulic laws apply quite satisfactorily enough for commercial purposes.

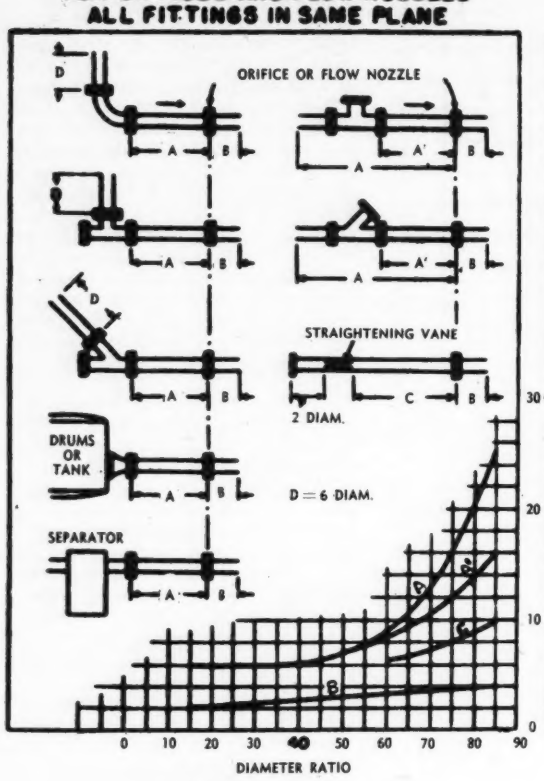
This phenomenon follows the general law of falling bodies, which is that the velocity is proportional to the square root of the distance fallen, or $V^2=2gh$ or $V=\sqrt{2gh}$. However, if the velocity is multiplied by the orifice area, which should give rate of flow, it is found that the figure so determined is larger than the actual rate of flow. It seems therefore that since the velocity is very close to the theoretical, some other effects are present which must be taken into account in order to use this phenomenon for the purpose of flow measurement.

If the hole, or orifice as it may be called, is cut round with perfectly square sides, it will be found that the jet issuing from it becomes smaller after leaving the orifice until a minimum diameter is reached. This minimum sized jet is called the *Vena contracta* and it is at this point that the fluid reaches its highest velocity, practically equal to the falling body velocity. It will not quite equal this velocity, due to friction with the sides of the orifice, change in temperature and density, change in velocity distribution, and impact effect on the inlet of the orifice.

The total of all of these effects, however, is relatively minor, compared to that of the vena contracta. The vena contracta effect is caused by the inertia of the fluid, as it is directed inward in approaching the orifice inlet edge and persists in that direction after it passes through until the inward component is absorbed by the forward component of velocity. For ordinary fluids, flowing under ordinary conditions, this effect may be depended upon and calculations may be based upon a ratio of vena contracta size to orifice size of 0.60, as long as the orifice size is small compared

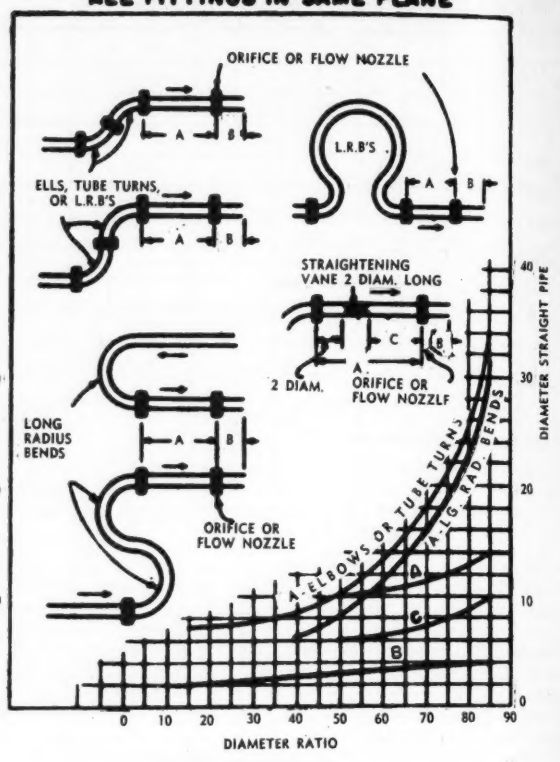
SCHEDULE 1

FOR ORIFICES AND FLOW NOZZLES
ALL FITTINGS IN SAME PLANE



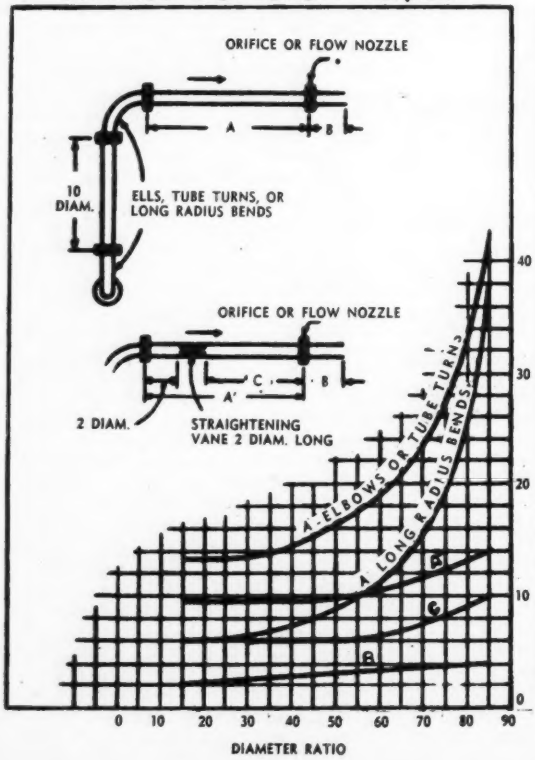
SCHEDULE 2

FOR ORIFICES AND FLOW NOZZLES
ALL FITTINGS IN SAME PLANE



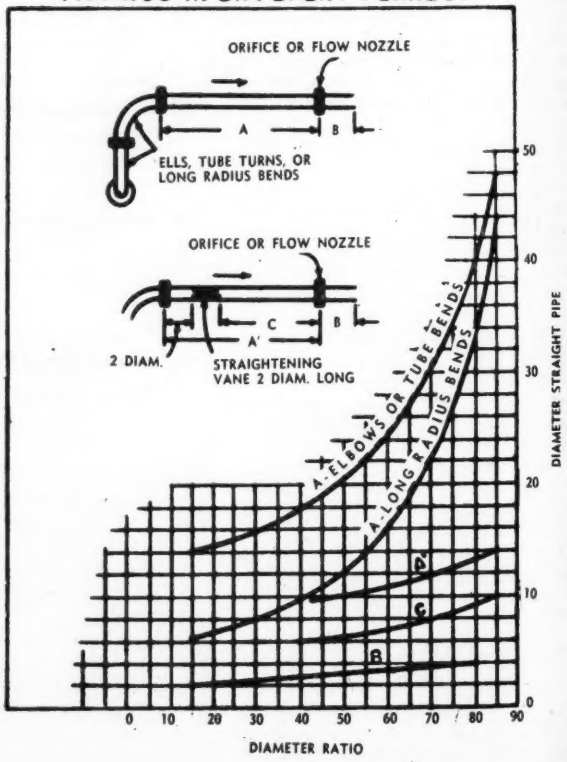
SCHEDULE 3

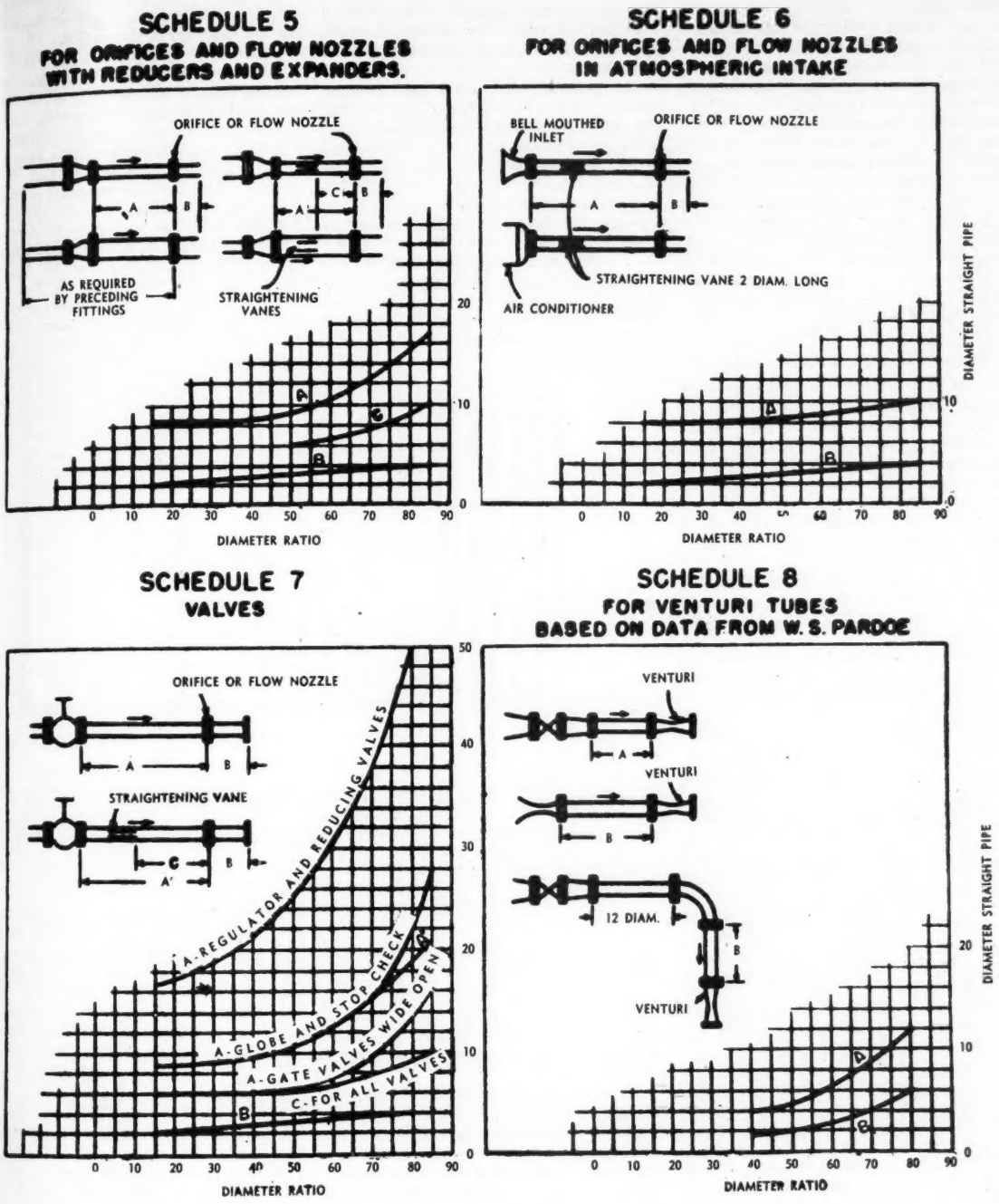
FOR ORIFICES AND FLOW NOZZLES
FITTINGS IN DIFFERENT PLANES


ORIFICE OR FLOW NOZZLE
10 DIAM.
ELLS, TUBE TURNS, OR LONG RADIUS BENDS
ORIFICE OR FLOW NOZZLE
2 DIAM.
STRAIGHTENING VANE 2 DIAM. LONG
A-ELBOWS OR TUBE TURNS
A LONG RADIUS BENDS
0 10 20 30 40 50 60 70 80 90
DIAMETER RATIO

SCHEDULE 4

FOR ORIFICES AND FLOW NOZZLES
FITTINGS IN DIFFERENT PLANES.


ORIFICE OR FLOW NOZZLE
ELLS, TUBE TURNS, OR LONG RADIUS BENDS
ORIFICE OR FLOW NOZZLE
2 DIAM.
STRAIGHTENING VANE 2 DIAM. LONG
A-ELBOWS OR TUBE BENDS
A LONG RADIUS BENDS
DIAMETER STRAIGHT PIPE
0 10 20 30 40 50 60 70 80 90
DIAMETER RATIO



	.0-.50 Ratio	.50-.60 Ratio	.60-.70 Ratio	.70-.80 Ratio
Fittings Allowed on outlet side in place of straight pipe	1. Tees 2. 45 ells 3. Gate valves 4. Separators 5. Y-fittings 6. Expansion jts.	1. Tees 2. Expansion jts. 3. Gate valves 4. Y-fittings 5. Separator (if inlet neck is one diam. lg.)	1. Gate valves 2. Y-fittings 3. Separator (if inlet neck is one diam. lg.)	1. Gate valve 2. Long radius bend

Fig. 4. Piping requirements for orifices, flow nozzles, and venturi tubes.

to the tank size. If the fluid is of a viscous nature, this will have to be modified also.

If the "hole" in the tank is flared smoothly outward to end in a short straight section of tubing, it will be found that the velocity issuing multiplied by the free area of the straight section of tubing will approximate very closely the actual volume of flow. This is because the inward component has been taken care of in the flare and the velocity is substantially uniform across the area of the tube. This kind of device is known as a *flow nozzle*. Its capacity, for the same area is greater than that of an orifice.

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From the above it is seen that such devices provide a very satisfactory means of measuring flow from or between tanks. All that is involved is to perform the arithmetic of converting velocity of flow through an area of known cross section into quantity rate of flow, and to obtain a convenient means of measuring the pressure difference across the orifice.

In most industrial cases, however, what is desired is the rate of flow in a closed pipe. The investigations cited have shown that the same laws, suitably modified to take care of the change in conditions, apply to orifices and nozzles installed in pipe lines.

Velocity in Pipe Line

The principal modification that must be made is to account for the existing velocity in the line. In order to be able to pass through the orifice or other head producing device, the fluid must approach the orifice with a finite velocity. This is also true in the tank example used previously, but there it was assumed that the area of the orifice was so small compared to the area of the tank wall that the approach was negligible. If the area of an orifice in a plate installed in a pipe line is very small compared to the area of the line, it will be found that practically the same thing is true.

Where, however, the area of the orifice is an appreciable fraction of the line area, the entire velocity through the orifice is composed partially of the induced velocity due to the pressure difference and partially of the already existing velocity in the line—commonly called the *velocity of approach*. This factor results, from a practical standpoint, in a modification of the 0.60 factor for the orifice, and in the coefficients for nozzles and venturi tubes. The resulting coefficient curve for orifices is shown in Fig. 2.

Turbulent Vs Laminar Flow

Another factor that needs to be taken into account is the effect of the profile of the stream as it approaches the orifice. This profile is affected by the velocity and by the viscosity of the fluid. The hydraulic relation of viscosity and flow in pipe lines was originally worked out by Sir Osborne Reynolds, and the correlating factors which take into account velocity, viscosity, density, and pipe size are known as *Reynolds numbers*.

For normally turbulent flow at Reynolds numbers greater than 40,000, the ratio of average velocity to center velocity, for new relatively smooth pipe will vary as shown in Fig. 10. This shows a relation varying from 0.78 for relatively rough pipe at a Reynolds number of 40,000 to 0.888 in smooth pipe at a Reynolds number of 10,000,000.[1] The result of this relation is a velocity profile about as shown in the upper illustration Fig. 3. Where the flow is laminar, however, the velocity distribution is parabolic with an average velocity equal to one-half of the center velocity, as shown in the lower part of Fig. 3.[2]

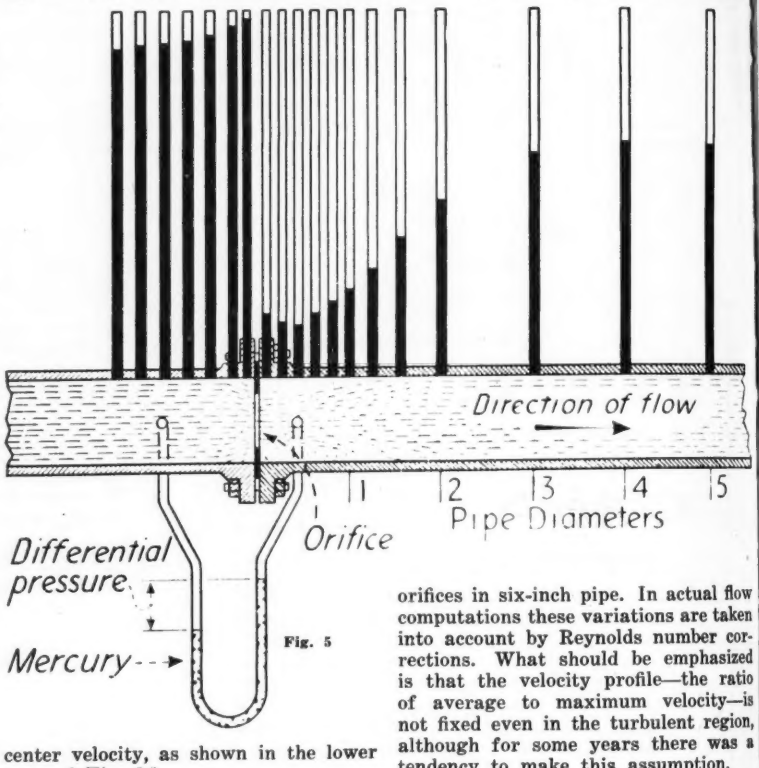

Fig. 5

It is evident that for the same rate of quantity flow in a pipe line, the fluid passing through the orifice in turbulent flow will have a greater average acceleration than that in laminar flow; or conversely, the laminar flow stream will not be accelerated as much in the center (where the orifice is) as a turbulent flow stream, and on that account more fluid will pass, for the same differential drop, for viscous than for turbulent flow. Since the center fluid is not accelerated so much, the inward component of velocity is reduced, and the vena contracta is larger.

It might be thought that the viscous drag of the fluid on the orifice edge would contribute further to this effect, but this is probably not the case, as the orifice is considered practically frictionless. Further contributing to this idea of the lack of friction is that the viscosity corrections are larger for large ratios of orifice diameter to pipe diameter than for small ratios.

Contrasted with this is the effect on nozzles and Venturi tubes. Here, the viscous drag is the greatest of the various tendencies and the capacity under viscous or laminar flow conditions is less than when turbulent flow exists.

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It is this matter of velocity distribution that makes installation details important. If the fluid approaching an orifice, or other head producing device, has had the normal flow pattern disturbed by piping bends, ells, valves, or other disturbing factors, the velocity distribution will not be normal.

If, for example, the orifice is preceded by two elbows in different planes of orientation, the flow is apt to swirl in the same manner in which water does in flowing out of a sink. Part of the velocity head measured in this case will be due to forward velocity, and part to tangential velocity; the result will be in error an unpredictable amount, since it is impossible to separate the two effects quantitatively. Any other disturbance which affects the flow distribution pattern will produce errors of

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The amount of free run of pipe necessary to permit the normal flow pattern to assert itself after some types

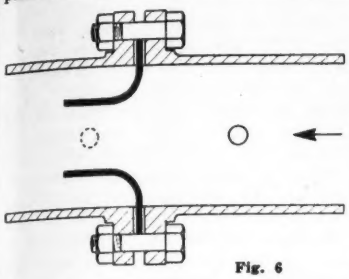

Fig. 6

of disturbance is shown in Fig. 4.[3] Where the free run of pipe is not available, the reassertion of normal flow pattern may be helped considerably by the use of straightening vanes, although this expedient is not to be considered equal to providing the longer straight runs of pipe.

Gas Flows

On gas flows, the density of the fluid is affected by three factors—the molecular weight, the pressure, and the temperature. On the basis of flowing conditions, the necessary correction factors are straight-forward arithmetic. However, since it is generally desired to express gas flow in terms of some set of standard conditions (that is, what the volume would be if the gas were brought to or measured at those conditions) additional arithmetic must be performed. Furthermore, not all gases follow the laws of Boyle and Charles perfectly, and the reduction of velocity expression at one set of pressure or temperature conditions to equivalent volume at standard conditions must take these discrepancies into account. These factors are also well known and corrections for them have been compiled into tables.

Another factor with respect to gases is that if the ratio of expansion caused by the orifice plate is high, the work used in internal expansion of the gas must be taken into account, and this will cause the calculations to become much more complicated. A general rule is that the ratio of expansion should not be greater than 0.96. This is ordinarily expressed by saying that the numerical value of the differential pressure in inches of water should not be greater than the numerical value of the absolute static pressure in pounds per square inch. If this rule is followed, the expansion factor may be safely neglected for ordinary conditions.

Differential Producing Devices

Before going on to the subject of differential pressure reading instruments, perhaps a word should be inserted here about orifice plates, flow nozzles, Venturi tubes and Pitot tubes.

Orifice Plate

A diagrammatic representation of an orifice plate installation is shown in Fig. 5. This illustrates how the pressure changes through the orifice and in the adjacent pipe lines. Actually this diagram is very much idealized, because turbulent flow has no such regular conformation as is suggested by this diagram.

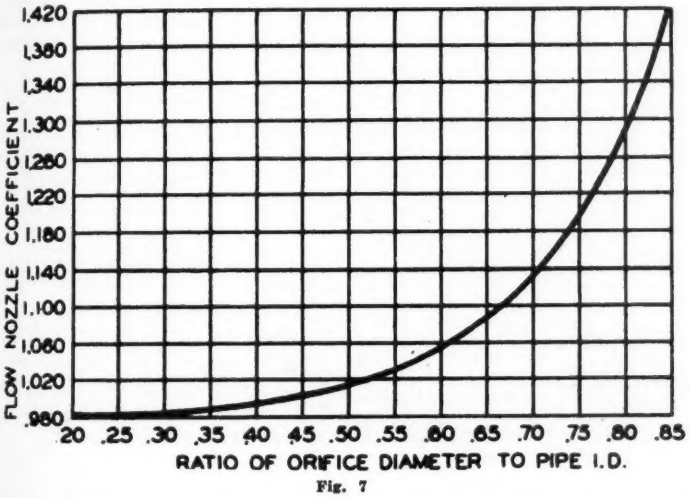

Fig. 7

Theoretically, the downstream tap should be taken at the location of the vena contracta, and this is done wherever practicable. However, the location of the vena contracta shifts with the diameter ratio, so that if it is necessary to change the orifice size, the tap location should be changed also. Very little error will be encountered, however, if the tap locations are a short distance either side of the vena contracta, and this leads to the use of the "flange taps" in which the connections are made through the flange holding the orifice, and spaced one inch upstream and one inch downstream.

Note that considerable amount of the differential pressure is dissipated in friction and eddy losses, so that there is a permanent loss of differential pressure. This loss varies with the diameter ratio; varying from practically 100 per cent at low ratios of orifice to pipe diameter, to 40 per cent at 80 per cent ratio.

Flow Nozzles

A diagram of a flow nozzle installation is shown in Fig. 6. As stated previously, flow nozzles may be used practically interchangeably with orifices, taking into account that there is no contraction correction necessary for the flow nozzle. The coefficient of a well-designed flow nozzle is about 0.98.

The coefficient curve for nozzles, including velocity of approach, is shown in Fig. 7. This shows that the capacity of flow nozzles is higher for the same differential pressure, than that of orifices. For this reason they are frequently used on high velocity flows, or in other locations where it is desired to keep the differential pressure to a minimum value.

The permanent losses are practically the same as for orifice plates. Compared to the orifice plate, the flow nozzle is more expensive, more difficult to install, and much more difficult to replace in the line, if necessary.

Venturi

The Venturi tube is used where it is desirable to keep the over-all pressure loss to a minimum. The decrease in size from the pipe to the throat, and the increase in size from the throat to the pipe, are made gradually as shown in Fig. 8. In this way eddy and friction losses are minimized.

There are two types of Venturi tubes generally used, known as *short cone* and *long cone* types, the difference being in the angle of the exit cones. The angle for the short cone type is ordinarily about 14 degrees, while for the long cone type it is 7½ degrees. With a long cone type Venturi tube, the loss is about 11 per cent of the differential for all diameter ratios; while with the short cone type, the maximum loss varies from about 28 per cent for low diameter ratios to about 15 per cent for a 75 per cent diameter ratio.

The Venturi tube has the same high coefficient as the flow nozzle, so that its capacity for the same differential pressure is high. Its disadvantages are the

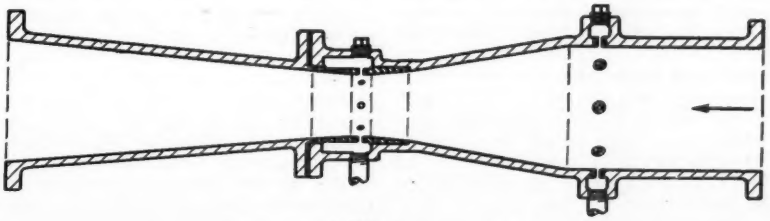

Fig. 8

to the tank size. If the fluid is of a viscous nature, this will have to be modified also.

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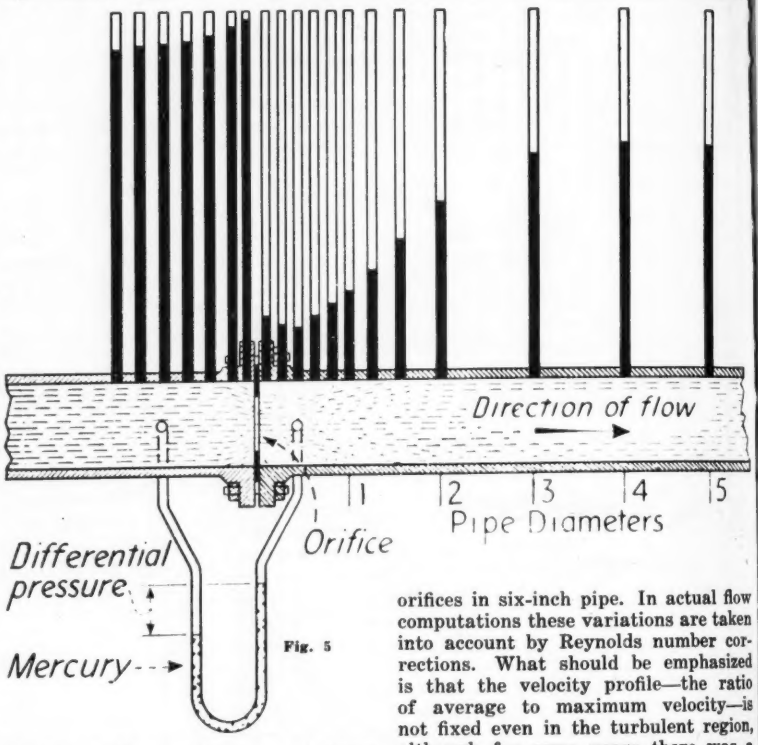

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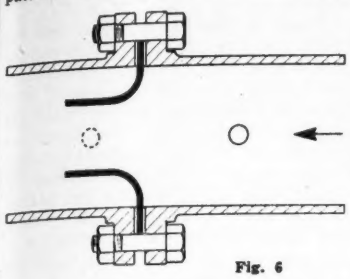

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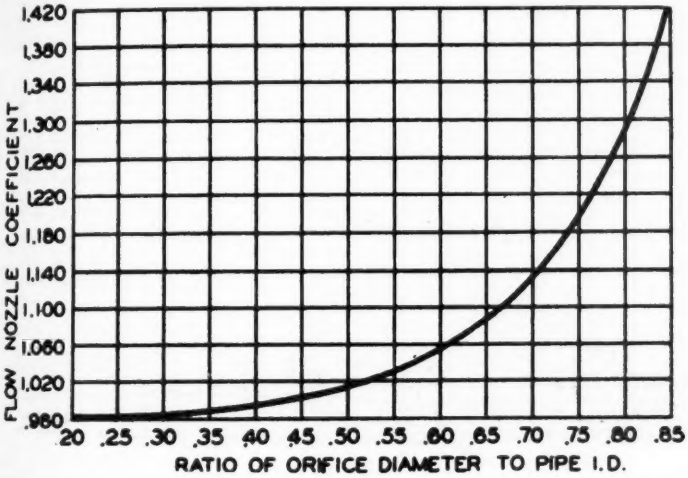

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Before going on to the subject of differential pressure reading instruments, perhaps a word should be inserted here about orifice plates, flow nozzles, Venturi tubes and Pitot tubes.

Orifice Plate

A diagrammatic representation of an orifice plate installation is shown in Fig. 5. This illustrates how the pressure changes through the orifice and in the adjacent pipe lines. Actually this diagram is very much idealized, because turbulent flow has no such regular conformation as is suggested by this diagram.

Theoretically, the downstream tap should be taken at the location of the vena contracta, and this is done wherever practicable. However, the location of the vena contracta shifts with the diameter ratio, so that if it is necessary to change the orifice size, the tap location should be changed also. Very little error will be encountered, however, if the tap locations are a short distance either side of the vena contracta, and this leads to the use of the "flange taps" in which the connections are made through the flange holding the orifice, and spaced one inch upstream and one inch downstream.

Note that considerable amount of the differential pressure is dissipated in friction and eddy losses, so that there is a permanent loss of differential pressure. This loss varies with the diameter ratio; varying from practically 100 per cent at low ratios of orifice to pipe diameter, to 40 per cent at 80 per cent ratio.

Flow Nozzles

A diagram of a flow nozzle installation is shown in Fig. 6. As stated previously, flow nozzles may be used practically interchangeably with orifices, taking into account that there is no contraction correction necessary for the flow nozzle. The coefficient of a well-designed flow nozzle is about 0.98.

The coefficient curve for nozzles, including velocity of approach, is shown in Fig. 7. This shows that the capacity of flow nozzles is higher for the same differential pressure, than that of orifices. For this reason they are frequently used on high velocity flows, or in other locations where it is desired to keep the differential pressure to a minimum value.

The permanent losses are practically the same as for orifice plates. Compared to the orifice plate, the flow nozzle is more expensive, more difficult to install, and much more difficult to replace in the line, if necessary.

Venturi

The Venturi tube is used where it is desirable to keep the over-all pressure loss to a minimum. The decrease in size from the pipe to the throat, and the increase in size from the throat to the pipe, are made gradually as shown in Fig. 8. In this way eddy and friction losses are minimized.

There are two types of Venturi tubes generally used, known as *short cone* and *long cone* types, the difference being in the angle of the exit cones. The angle for the short cone type is ordinarily about 14 degrees, while for the long cone type it is 7½ degrees. With a long cone type Venturi tube, the loss is about 11 per cent of the differential for all diameter ratios; while with the short cone type, the maximum loss varies from about 28 per cent for low diameter ratios to about 15 per cent for a 75 per cent diameter ratio.

The Venturi tube has the same high coefficient as the flow nozzle, so that its capacity for the same differential pressure is high. Its disadvantages are the

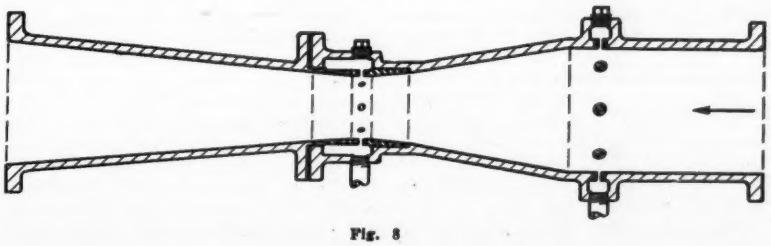

Fig. 8

same as those of the flow nozzle, except to an even higher degree, as it is higher in first cost, more expensive to install, and much more difficult to replace in the line than the orifice plate. It possesses, however, another operating advantage: it does not foul up so readily when used on dirty fluids as does an orifice, and will resist the attack of abrasive material suspended in the measured fluid much better.

Pitot Tube

The Pitot tube is an entirely different kind of device. Its function is to determine the velocity head of the flowing fluid. It accomplishes this on the basis of stopping the flow in a small area and measuring the resulting rise in pressure. Any flow stopped almost instantaneously will rise in pressure practically to the pressure at the source from which it came, minus the intervening pressure loss due to friction. Thus it may be considered that the impact pressure rise represents the drop in pressure necessary to accelerate the fluid to its existing velocity from a head or pressure of zero velocity.

The disadvantages of the Pitot tube are that it takes only spot readings which must be interpreted in terms of average velocity in order to determine quantity rate of flow. It is on that account highly susceptible to variations from normal flow distribution in the line. Furthermore, it is completely inflexible and the readings obtained from it are of such a small magnitude for ordinary flows that they are difficult to read and interpret correctly.

The Pitot tube does possess the advantages that it causes practically no pressure loss in the line, and can be readily installed in, or removed from, lines while under pressure. It is frequently used to explore velocity distribution in lines.

Reading Instruments

The function of the reading instruments is to make the differential pressure, developed by any of the differential pressure devices, available in an easily usable form. In most industrial cases of measuring liquids under pressure, it is impractical to run pipes up in the air a distance which will develop a hydraulic head equal to the line pressure, and determine the difference in heads in the two tap-lines by visual observation. For gases, it is really impossible to visualize a fluid column susceptible to visual observation.

Therefore the customary procedure is to read the differential pressure directly on special differential pressure gages. The simplest form of such gage is a U-tube manometer. If the line fluid being measured is a liquid lighter than water, or a gas, water may be used as the manometric fluid; if the fluid is water, or a liquid heavier than water, some heavier liquid must be used. In any case, the manometric liquid should be denser than the line fluid.

This means that the manometer will not read direct in terms of inches or feet head difference of the flowing fluid, except in the rare case where the density of the line fluid is exactly one-half that of the manometer liquid. Therefore the reading of the manometer must be converted into equivalent head by a multiplier. These multipliers are incorporated in the ordinary flow equations.

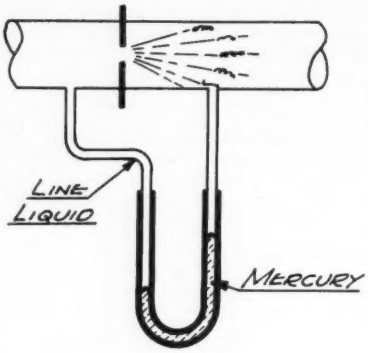

Fig. 9

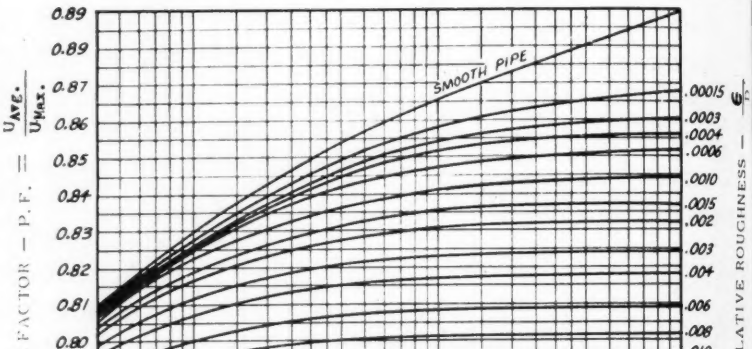

Fig. 10

It is customary to express the range of manometers and other reading instruments in terms of inches of water and the multipliers incorporated in the equations are so expressed. However, the effective calibration of any U-tube manometer is changed by a change in density of the fluid in contact with the manometer fluid. In the case of gases, except at extremely high pressures, the density of gas is so small compared to that of a manometer fluid that this effect may ordinarily be neglected.

In the case of liquid above the manometer liquid, the displacement of the manometer liquid in balancing differential pressure is partially offset by the column of line liquid in the high pressure leg of the manometer up to the height of the manometer liquid in the low pressure leg. This effect is shown in Fig. 9. The amount will depend on the density of the line liquid as compared with the manometer liquid. Since the customary manometer uses mercury as a liquid, particularly the ordinary recording instruments used as flow meters, this effect has come to be known as the "liquid-on-mercury" correction.

Where a sealing liquid is used between the line liquid and the manometer liquid, the correction is based on the density of the sealing liquid; or if there is substantial movement of the interface between the line liquid and the sealing liquid, the correction is a compound one taking into account the densities of both the line and sealing liquids and the displacement of each. All these effects are incorporated in the equations in the common handbooks on Flow Measurement.

However, a strong criticism may be made of the manner in which these corrections are made in most handbooks. It has been shown that there are two ways in which the density of the flowing fluid, particularly a liquid, may affect the calculations and interpretation of the readings of a manometer type instrument. One is the relation between the calibration of the instrument and the actual head difference across the orifice and this is a square root function; the other is the density of the fluid on top of the manometric liquid, and this is also a square root function. Also it is possible to incorporate in the calculations the reduction of quantity of liquid at line condition of density to volume at some other density condition, generally referred to as "Storage" conditions.

Recently a number of meters have appeared on the market which do not make use of the manometric method of reading differential pressure, and hence are not affected as to effective calibration by the density of the fluid in the meter bodies. Therefore, it is not necessary to use the second correcting factor, but the way in which these factors are incorporated in the equations makes it very difficult for the casual or infrequent user of them to determine which

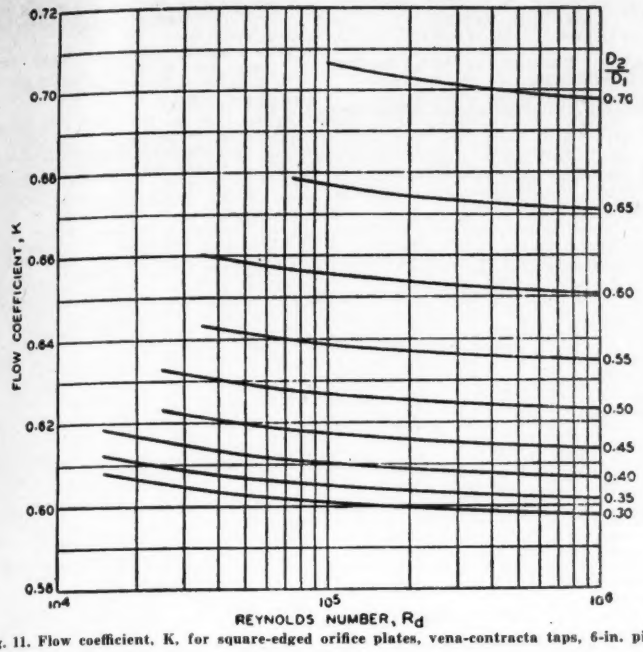

Fig. 11. Flow coefficient, K, for square-edged orifice plates, vena-contracta taps, 6-in. pipe.

is which, and which one must be retained and which one may be omitted. These expressions as used in the equations are not incorrect, and are entirely clear, apparently, to those who deal with the equations continually or frequently, but they are very confusing to those who have occasion to use this information only infrequently.

Summing up, commercial flow measurement involves:

1. Changing velocity in a flowing stream by inserting a contraction in the flow line.
2. Determining the relation between the pressure differential so created and quantitative rate of flow.
3. Measurement of the differential pressure so created.
4. Interpretation and conversion of the measurement into desirable or usable values.

This paper has attempted to show that the fundamental principle of the flow meter covered under points 1 and 2 is essentially simple, and that the complications in its use arise for the most part from the interpretation of the readings.

REFERENCES

(1) "Pipe Factors for Quantity Rate Flow Measurements with Pitot Tubes," R. J. Folsom and H. W. Iversen. Paper presented at ASME Annual Meeting, New York, Nov. 20-Dec. 3, 1948.

(2) "The Relationship Between Reynolds Number and Velocity Distribution," L. S. Rhodes, *ASME Journal of Applied Mechanics*, March 1943.

(3) "Piping Arrangements for Acceptable Flowmeter Accuracy," R. E. Sprenkle. *Trans. ASME*, 1945, Vol. 67, p. 345.

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John Q. Bass, 1517 Longwood Dr., Baton Rouge. La. Tel: 3-0283
Meeting monthly, L.S.U. Physics Bldg.

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May 2, Presidents night.

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Richard F. Rieman, 3550 Euclid St., Indianapolis, Ind. Tel. CH 7462
First Tuesday, Meeting at 7:30 P. M.

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Fred Gilmer, 418 Beech Ave., Charleston, W. Va.
First Monday, Dinner at 6:15 P.M., Meeting at 8:00 P.M., Kanawha Hotel
May 7, "Stump the Experts" program.

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Floyd E. Ertsman, Rm. 1420 Fisher Bldg., 343 S. Dearborn St., Chicago 4, Ill. Tel: WE 9-0686
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A. H. Staud, 1004 Michelson Lab., USNOTS, China Lake, Calif. Tel: 77882
Fourth Thursday, Meeting at 8:00 P.M., Michelson Lab, USNOTS.

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L. W. Greene, 181 Market St., Aurora, Ind.
Second Monday, 8:00 P. M., Eng'r. Society Hqs.

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A. E. Ehrke, 5805 Euclid Ave., Cleveland, Ohio. Tel: Ex 1-5454
Fourth Wednesday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., Cleveland Eng'r. Society, E. 19th St.

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May 22, "Automatic Indication in Quality Control," T. S. Cawthorne, T. S. Cawthorne Co. Joint meeting with AIEE.

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Last Monday, 8:00 P. M., Engineers Club.

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H. H. Schmall, 3706 Benton Blvd., Kansas City 3, Mo. Tel: AR 4808
First Tuesday, 7:30 P.M., U. of Kansas City.
May 1, "Principles of Automatic Control," ISA Color-sound film by G. F. Akins, J. Kowalski, Kodak Co. Also tour, lecture on "Gage Laboratory," Place: Midwest Research Institute.

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Fourth Tuesday, Meeting at 8:00 P.M., Seagram Auditorium.

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Last Monday, 8:00 P. M., Mechanics' Institute.

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Fred L. Crabbe, Malcolm W. Black & Co., Inc., 41 East 42nd St., New York 17, N. Y. Tel: Vanderbilt 6-2960.
First Tuesday, Dinner at 6:00 P. M. Meeting at 8:00 P.M., Essex House, Newark.
May 1, "Recent Advances in Measurements with Tube Systems," R. E. Clarridge, Taylor Inst. Co.

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W. H. Haney, 2927 Music St., N. O. 22, La.
No Regular Date, Meeting at 8:00 P.M.

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F. B. Leslie, 8856 Commonwealth Blvd., Bellerose 6, N. Y. Tel: FI 7-0645
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April 23, "Air Operated Controls," J. A. Pellettere, Gulf Oil Corp.
May 23, "Refrigeration Control," Frank Salisbury, E. Kodak Co.

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April 23, "Instrumentation in Chemical Plant Design," R. L. Hurley, Jr., DuPont. Inspection Committee: "Recent Developments in Screw Threads," R. A. Fry, Westinghouse.
May 28, Lecture and visit to Carnegie Inst. Technology Synchro-Cyclotron; Speaker: Gen. Henman, C.I.T. Inspection Committee: "Legal Aspects of Procurement," Clair V. Duff of Duff, Stockdale & Doyle, Attys. at Law.

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R. C. Schwarz, Jr., 1201 Granite Bldg., Rochester 4, N. Y. Tel: Monroe 4610R
Fourth Tuesday, Meeting at 8:00 P.M., Univ. of Rochester, Physics Lecture Hall.
April 24, "Practical Uses of Frequency Response Methods for Studying Industrial Process Control," D. W. St. Clair, Kodak Co.

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Raymond E. Miller, 20-224 Naval Ord. Lab., White Oak, Md. Tel: JU 7-6742
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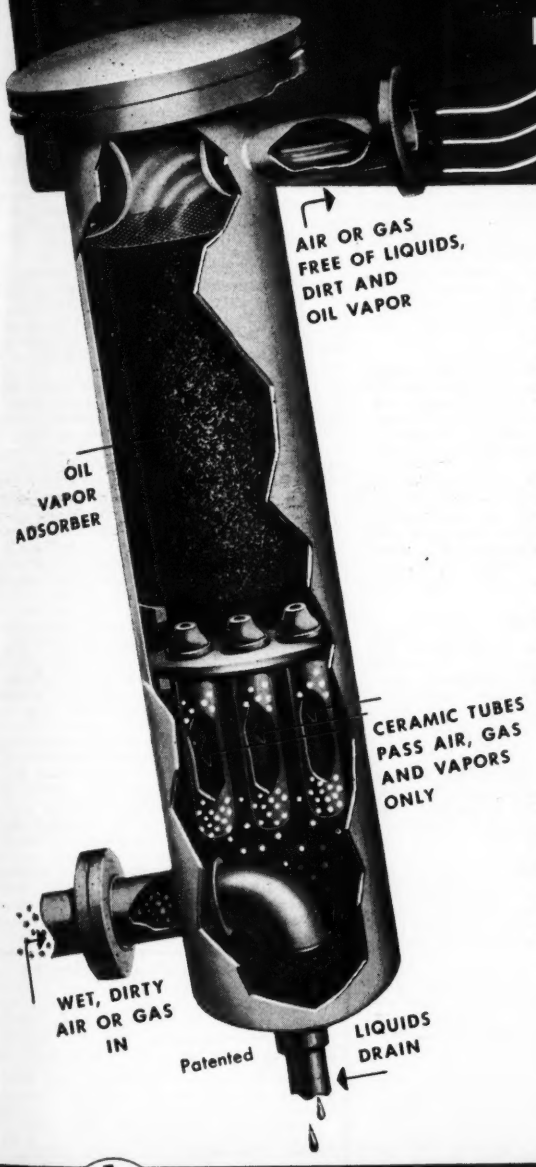
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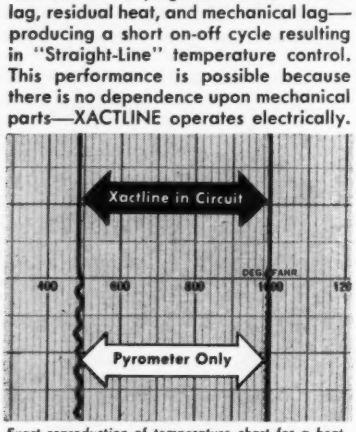
TEMPERATURE CONTROL
with
XACTLINE

ELIMINATE
Overshooting
Undershooting

Are you going to continue to put up with that troublesome overshooting and undershooting inherent in your conventional pyrometer control—especially when it is so easy to eliminate that saw-tooth effect?

Put XACTLINE in the control circuit. XACTLINE anticipates the temperature changes—before they occur. And too, it nullifies the varying amounts of thermal lag, residual heat, and mechanical lag—producing a short on-off cycle resulting in "Straight-Line" temperature control. This performance is possible because there is no dependence upon mechanical parts—XACTLINE operates electrically.



Exact reproduction of temperature chart for a heating process showing the comparison of the "Straight-Line" temperature control produced by XACTLINE and the saw-tooth curve obtained with only conventional control.

XACTLINE is applicable to any indicating or recording pyrometer control of the millivoltmeter or potentiometer type. It should be used wherever close temperature control is required—any type of electrically heated oven, furnace, kiln, injection molding machine, and fuel-fired furnaces equipped with motor-operated or solenoid valves.

XACTLINE is a complete unit. No adjustment or coordination with the control instrument is required regardless of the size of the furnace, length of the heating cycle, or size of the load. Installation is very simple—can be either flush or surface mounted.

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Manufacturers' New Literature

In this department we report new literature pertaining to Instrumentation, received from the manufacturers. We urge readers to request ONLY those bulletins which will be of value to them. Use the Postage-free Order Card on Page 485.

Requests for literature FROM ABROAD should be made on company letterhead and mailed DIRECTLY to the manufacturers.

T-268 INSTRUMENTATION FOR GASOLINE PROCESSING. 28-page Vol. 3, No. 3 issue of "Taylor Technology," features articles on instrument applications to gasoline, rubber, canning, and meat packing industries as well as articles on "Transet Tri-act" controller, averaging liquid-level controllers and testing pressure instruments.—Taylor Instrument Companies, Rochester 1, N. Y.

T-269 INDICATING PYROMETER CONTROLLER. 4-page Bulletin W-1811 illustrates and describes maker's stock instruments for immediate delivery; includes pressure gages, thermometers, dairy controllers, indicating temperature controllers, recording millivoltmeters, voltmeters, ammeters and pyrometers; includes specifications and applications.—The Bristol Co., Waterbury 91, Conn.

T-270 SINGLE CONTROL VALVE. 32-page Publication 4520 illustrates and describes maker's "Zeolite" softeners with hydromatic single control valve; discusses the sodium zeolite softening process, definition of terms, selection of materials and steps of operation.—Cochrane Corp., Philadelphia 32, Pa.

T-271 VACUUM COATING UNITS. 4-page data sheet describes in detail the construction, capabilities and performance of maker's vacuum coating units; information summerized in chart form.—Vacuum Equipment Dept., Distillation Products Industries Div., Eastman Kodak Co., Rochester 3, N. Y.

T-272 PROCESS CONTROL. 4-page Instrumentation Data Sheet 11.0-4 illustrates and describes maker's new apparatus to provide process control by measuring refractive index; discusses uses, equipment needs, method of measurement, operation and design features.—Industrial Div., Minneapolis-Honeywell Regulator Co., Philadelphia 44, Penna.

T-273 STRAIN-GAGE INDICATOR. 2-page bulletin illustrates and describes maker's "Model 1020" self-contained portable strain-gage indicator.—Cole Instrument Co., 1320 S. Grand Ave., Los Angeles 15, Calif.

T-274 INDICATING GAGE. 28-page Bulletin 209G illustrates and describes maker's indicating gages, recorders and testers; includes graduations, standard specifications, accessories and weights.—Crosby Steam Gage & Valve Co., Boston 29, Mass.

T-275 VALVE SIZING CHART. 2-page Supplement 3, Catalog 70 gives steam valve and butterfly valve sizing chart; discusses sample problems and use.—Fischer & Porter Co., Hatboro, Penna.

T-276 CONTROLLERS, RECORDERS, ETC. 6-page Bulletin W-1817 describes 34 of maker's instruments, part of 60th Anniversary; includes diesel engine pyrometer, thermometer receiver, meta-wattmeter transmitter, viscosity recorder, air-operated controllers, etc.—The Bristol Co., Waterbury 91, Conn.

T-277 VACUUM-TUBE VOLTMETER. 48-page booklet "Servicing Radio and Television with a Vacuum-tube Voltmeter" illustrates and describes the vacuum-tube voltmeter, radio receiver tests and measurements, audio amplifier tests and measurements, television receiver tests and miscellaneous applications.—Radio Tube Div., Sylvania Electric Products, Inc., 1740 Broadway, New York 19, N. Y.

T-278 POTENTIOMETER CONTROLLERS. 4-page Specification Sheet 189 illustrates and describes maker's multi-record "Electronik" strip-chart potentiometer controllers; includes general specifications, control forms and dimensions.—Industrial Div., Minneapolis-Honeywell Regulator Co., Philadelphia 44, Penna.

T-279 TIMERS. 2-page catalog illustrates and lists maker's line of items developed and manufactured for use in hydraulic, photographic, automotive and electronic applications.—Gadget, Inc., 3629 N. Dixie Drive, Dayton 5, Ohio.

T-280 DIELECTRIC CONSTANT METER. 2-page Bulletin 280 illustrates and describes maker's "Di-electric" constant meter for measuring the dielectric constant of liquids and demonstrating the principles related to this property.—Eberbach & Son. Co., Ann Arbor, Mich.

T-281 LIQUID-LEVEL GAGES. 24-page Bulletin L-700 illustrates and describes maker's liquid-level gages for recording, indicating, controlling and telemetering; discusses principle of operation, typical applications and engineering diagrams.—The Bristol Co., Waterbury 20, Conn.

T-282 SOUND EQUIPMENT. 34-page Catalog 11Ay illustrates and describes maker's mixer controls, attenuators, grid controls, turntable faders, volume unit indicators, decibel and V. U. meters etc.; includes specifications and price list.—Cinema Engineering Co., 1510 W. Verdugo Ave., Burbank, Calif.

T-283 TACHOMETERS. 20-page catalog N-27 illustrates and describes maker's "Micromax" and "Speedomax" speed recorders, discusses and compares the principle of operation and discusses the advantages of both.—Leeds & Northrup, 4934 Stenton Ave., Philadelphia 44, Penna.

T-284 SERVO AMPLIFIER. 4-page Instrumentation Data Sheet 10.20-3 features article "Servo Amplifier System Provides High Sensitivity with Extremely Low Stray Level"; discusses applicability, operation, amplifier characteristics, etc.—Industrial Div., Mineapolis Honeywell Regulator Co., Philadelphia 44, Penna.

T-285 CAPACITORS. 4-page Issue 139 illustrates and describes maker's miniature "Demicon" paper capacitors in tubular metal casings available in two types: Dykanol "C" impregnated

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and high temperature wax impregnated.—Cornell-Dubilier Electric Corp., South Plainfield, N. J.

T-286 STEAM CAPACITY. 2-page "Mipco" steam capacity chart for determining steam capacity required from safety valves to give 100 percent protection in case of pressure reducing valve failure.—Marine & Industrial Products Co., 3731 Filbert St., Philadelphia 4, Penna.

T-287 VACUUM GAGE. 4-page Bulletin Z-251 illustrates and describes maker's new "Zimmerli" gage (with 2 side outlets instead of one) for vacuum or differential pressure readings.—Scientific Glass Apparatus Co., Inc., 120 Lakewood Terrice, Bloomfield, N. J.

T-288 HIGH-FREQUENCY RESISTORS. 4-page Bulletin F-2 illustrates and describes maker's water-cooled "IRC High Frequency-High" power resistor for TV, FM and dielectric heating applications; discusses characteristics, specifications and installation.—International Resistance Co., 401 N. Broad St., Philadelphia 8, Penna.

T-289 DRAWING INSTRUMENTS. 14-page booklet illustrates and relates the historical background of drawing instruments and modern developments in drafting practice.—V & E Manufacturing Co., 758 S. Fair Oaks Ave., Pasadena 20, Calif.

T-290 PIPE LINE FILTERS. 8-page Bulletin B-1A illustrates and describes maker's "Stay-new" pipe line filters for air and other gases; gives applications and specifications for 75 filters, including pressure and vacuum types.—Dollinger Corp., Rochester 3, N. Y.

T-291 MANUAL VALVES. 44-page Catalog 1B-1 illustrates and describes maker's "Shear-Seal" valves; discusses range of shut-off, selector and manipulator valves for pressures from 0 to 6000 psi; explains "shear-seal" principle.—Barksdale Valves, 1566 E. Slauson, Los Angeles 11, Calif.

T-292 VOLTMETERS. 12-page Bulletin 12 illustrates and describes maker's battery-operated, RF and sensitive peak-to-peak voltmeters; includes specifications and accessories.—Ballantine Laboratories, Boonton, N. J.

T-293 RESISTORS. 2-page bulletin illustrates and describes maker's lug-terminal and lead-terminal type precision resistors; includes dimensions, wattage ratings and resistance range.—Mepco, Inc., 37 Abbett Ave., Morristown, N. J.

T-294 RADIOACTIVITY MEASUREMENT. 8-page January 1951 illustrated price list presents maker's scalers and accessories, sample holders and changers, counting rate and survey meters, Geiger-Mueller tubes and accessories, sample preparation material, safety equipment, sources and radiochemicals.—Tracerlab, 130 High St., Boston 10, Mass.

T-295 LABORATORY PUMPS. 12-page brochure illustrates and describes maker's "Carson-Cerveny Micro-Bellows" pumps; discusses construction, operation, capacity, applications, maintenance, repair and parts.—Research Appliance Co., Box 413 West View Road, Pittsburgh 9, Penna.

T-296 PRESSURE REGULATOR. 56-page Catalog 51 illustrates and describes maker's steam and liquid control equipment: includes pressure, pump, temperature and water-pressure regulators; relief, diaphragm, solenoid, float and motor-operated balanced valves, etc.; lists dimensions, capacities and prices.—O. C. Keckley Co., 400 W. Madison St., Chicago 6, Ill.

T-297 AMPLIFIERS. 4-page bulletin illustrates and describes maker's "Mecha SA203" amplifier; includes specifications, graphs and engineering diagrams.—Servomechanisms Inc., Old Country & Glen Cove Roads, Mineola, N. Y.

T-298 POTENTIOMETERS. 4-page Bulletin 162 illustrates and describes maker's "Type 162" single turn linear and non-linear precision potentiometers designed for military airborne instrumentation, computor control or similar applications, includes mechanical features, electrical features, specifications and ordering information.—George Rattray & Co., Inc., 92-93 Union Hall St., Jamaica 5, N. Y.

T-299 ACCELEROMETERS. 4-page bulletin

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THE ELECTRONIC STANDARD CELL

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The accurate HASTINGS Electronic STANDARD CELL with many *new* features is now available for use wherever a highly stable d.c. voltage source is needed. It is not affected by extremes of temperature and will not be damaged by momentary short circuits. Hastings' Model FC-X is built entirely to customer specification for operation within ranges of 0 to 100 volts output and 0 to 30 milliamperes load. Transformers are hermetically sealed and condensers are oil-filled, important factors contributing to rugged dependability. Its compact size, 7" x 8" x 10" and light weight, 10 lbs., including attractive gray case, help make the HASTINGS Electronic Cell the choice for production and laboratory installations. Write for a copy of our data sheet on this new Hastings unit.

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RIPPLE: Less than 0.01% on no load models.
POWER: 90-130 V a-c 60 cycle. (Will also work on 400 cycles.)
DIMENSIONS: 7"x8"x10"; weight, approximately 10 pounds.
CONNECTIONS: Input—6-foot cable terminating in standard 115-volt plug.
Output—Binding Posts.

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Model	No Load Voltage	Internal Resistance OHMS	Max. Current Drain Ma.	Voltage At Max. Current Drain
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FC-10	10.00	428	7.0	7.0
FC-10B	Load Always Connected	2600	30.0	10.0
FC-A	1.018	47	10.5	0.525
FC-1	1.00	46	10.4	0.520
FC-X	Voltage and	Load can be	specified	

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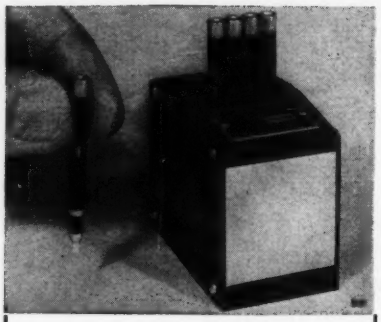

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● BALANCE TO LESS THAN .001" PER "G" AT 12" OPTICAL DISTANCE.

A Super-Sensitive galvanometer especially developed by Midwestern for use in recording signals direct from source, without amplification. Because of its precision balance, it is especially valuable in applications where instruments are subjected to extreme vibration—such as in aircraft testing. No special shock mounting is normally required.

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This galvanometer has individual circuits for both terminals of the elements. Element tube O.D. is .187", and length is 2.062". It is used in Midwestern's magnet structure M-153. Center distance between elements is .195". Characteristics of elements are shown below.

SS Type	Nominal Undamped Natural Frequency	D.C. Sensitivity 12" Optical Arm (Undamped) Ma/in.	Nominal Galvanometer Resistance Ohms
106-100	100	0.005	35
106-150	150	0.012	35
106-200	200	0.020	35

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illustrates and describes maker's self-recording accelerometer; discusses record making and playback, fields of application and specifications.—Instrument Div., Engineering Research Associates, Inc., 1902 W. Minnehaha Ave., St. Paul W4, Minn.

T-300 LIQUID METER. 4-page bulletin illustrates and describes maker's "Figure 460 Xacto Meter" designed to handle a variety of liquids; includes specifications and engineering diagrams.—Bowser, Inc., Fort Wayne, Ind.

T-301 OSCILLATOR. 4-page bulletin illustrates and describes maker's "Model M-2" low-distortion wide-range oscillator; includes specifications and engineering diagrams.—Southwestern Industrial Electronics Co., 2831 Post Oak Road, P. O. Box 13058, Houston 19, Texas.

T-302 LIQUID MEASUREMENT. 8-page Bulletin W-2 illustrates and describes maker's "Densitrol" for continuous measurement and control of liquid density and for use in control or recording of blending, mixing, separation, dilution and concentration of industrial process liquids.—Precision Thermometer & Instrument Co., 1434 Brandywine St., Philadelphia 30, Penna.

T-303 STRAIN GAGE. 2-page Bulletin 174 illustrates and describes maker's "SR-4" temperature-compensated strain gage; includes specifications and price list.—Testing Equipment Dep't., Baldwin-Lima-Hamilton Corp., Philadelphia 42, Penna.

T-304 BELLOWS. 16-page catalog illustrates and describes maker's "Flexon" stainless steel and brass bellows, bellows assemblies and bellows devices; discusses the manufacture, design, specifications, dimensional standards and application.—Chicago Metal Hose Corp., Maywood, Ill.

T-305 MOISTURE TESTER. 4-page Bulletin MT-250 illustrates and describes maker's "Universal" Moisture Tester for determining moisture content of organic and inorganic substances.—Sheldrick Manufacturing Co., Upper Sandusky, Ohio.

T-306 THERMOMETERS. 4-page Bulletin 51-129 illustrates and describes maker's mercury-actuated dial thermometers; includes complete engineering specifications, construction features and purchasing information.—Palmer Thermometers, Inc., 2501 Norwood Ave., Cincinnati 12, Ohio.

T-307 BAROMETER. 2-page bulletin illustrates and describes maker's "Micro" precision barometer, lists pressure ranges and general specifications.—American Paulin System, 1847 S. Flower St., Los Angeles 15, Calif.

T-308 SPECTROSCOPY. 28-page house organ, Vol. 20, No. 3 issue of "The Laboratory," features article "Spectroscopy Turns On the Heat" as well as articles on American-made polarimeters, illuminator for gas-analysis units, electrocarbon meter, Zahn viscometer, metallography and "Cartesian" manostat.—Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Penna.

T-309 CAPACITANCE METER. 8-page house organ, Vol. XXV, No. 9 issue of "The General Radio Experimenter," features article on "Type 1612-AL" RF capacitance meter including illustrations and specifications.—General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.

T-310 LINEAR VARIABLE DIFFERENTIAL TRANSFORMERS. 4-page bulletin illustrates and describes maker's linear and angular accelerometers, pressure transducers, linear variable differential transformers and rotary variable differential transformers, rotary accelerators, slip rings and recorder systems.—Schaevitz Engineering, Camden, N. J.

T-311 REFRACTORY PROTECTION TUBE. 2-page Bulletin F-3 illustrates and describes maker's "Corundum FA-90" primary protecting tube; includes specifications and price list.—Wheatstone Corp., 2436 Reading Road, Cincinnati 2, Ohio.

T-312 CARBON CONTROL. 8-page house organ Vol. 10, No. 4 issue of "Modern Precision," features illustrated articles on application of maker's instruments to metals, ceramics, power and process industries as well as the research, teaching and testing fields.—Leeds and Northrup Co., 4907 Stenton Ave., Philadelphia 44, Penna.

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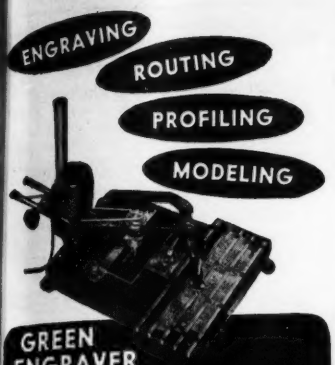

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T-313 INSTRUMENT ACCESSORIES. 80-page 3 x 4-in. condensed catalog illustrates and describes maker's drumshaft assembly, instrument supports, counters, charting paper, inks, tube monometer, power unit, recorders, timers etc.—Gorrell & Gorrell, Haworth, N. J.

T-314 LINE NOISE MONITOR. 2-page bulletin illustrates and describes maker's "Raychronix Model B-2" noise monitor for detecting line disturbances which may impair low-level or small-pulse counting.—Radioactive Products, Inc., 443 W. Congress St., Detroit 26, Mich.

T-315 RUBBER PARTS. 8-page booklet discusses maker's "Bonded-Rubber" parts and their applications to industry.—Lord Manufacturing Co., Erie, Penna.

T-316 INDUSTRIAL X-RAY. 8-page Bulletin 21250 illustrates and describes x-ray films, industrial cassettes, high-intensity illuminator, defraction film measuring scale and other accessories.—Ricker X-Ray Corp., 300 Fourth Ave., New York 10, N. Y.

T-317 MAGNETIC RECORDING COMPONENTS. 4-page Bulletin 15-M illustrates and describes maker's "RE-2" recording head, "PB-10" play-back head, "ER-1" erasing head, "Type 9205" tape and film degausser and "8905" magnetic erasing pencil.—Cinema Engineering Co., 1510 Verdugo Ave., Burbank, Calif.

T-318 STRAIN MEASUREMENTS. 2-page Bulletin 331 illustrates and describes "H-42A Strainalyzer" for dynamic strain and vibration studies from 0 to 50,000 cps.; discusses general uses and complete specifications.—Baldwin-Lima-Hamilton Corp., Philadelphia 42, Penna.

T-319 PHOTO-RECORDING. 16-page house organ, Vol. 12, No. 3 issue of "The Oscillographer," features article on new equipment available for single-frame photo-recording.—Instrument Div., Allen B. Du Mont Laboratories, Inc., 1000 Main Ave., Clifton, N. J.

T-320 TESTING MACHINES. 8-page Bulletin 40 illustrates and describes maker's hydraulic type "Super L" testing machines with "selectrange" indicating system; includes specifications and engineering diagrams.—Tinius Olsen Testing Machine Co., Easton Road, Willow Grove, Penna.

T-321 RHEOSTATS. 2-page house organ, February 1951 issue of "The Ohmite News," features article on application of maker's rheostats to mechanized continuous coal-miner; discusses "Riteohm" precision resistors and ceramic open-type tap switches.—Ohmite Manufacturing Co., 4835-41 Flourney St., Chicago 44, Ill.

T-322 RADIOACTIVITY SCALER. 2-page bulletin illustrates and describes maker's "Raychronix Model A-4" scaler designed for use with self-quenching counter tubes operating in the Geiger region; includes applications and specifications.—Radioactive Products Inc., 443 W. Congress St., Detroit 26, Mich.

T-323 MILLIVOLTMETER. 16-page house organ, Vol. 16, No. 2 issue of "The C-D Capacitor," features article "An Inexpensive A. F. Millivoltmeter"; includes circuit diagrams, construction data, calibration and use.—Cornell-Dubilier Electric Corp., Hamilton Blvd., South Plainfield, N. J.

T-324 DIE-STAMPED CIRCUITS. 16-page booklet describes and illustrates maker's process of die-stamping electrical and electronic circuits and parts.—Franklin Airloop Corp., 43-20 34th St., Long Island City 1, N. Y.

T-325 Q CONTROL. 4-page Bulletin A-4 illustrates and describes maker's Q control; complete specifications and characteristics including charts and graphs.—International Resistance Co., 401 N. Broad St., Philadelphia 8, Penna.

T-326 GROUND TESTING INSTRUMENTS. 2-page Data Sheet 26-43 illustrates and describes maker's "Model 243" and "Model 263" ground and soil resistivity testing instruments.—Associated Research, Inc., 3758 W. Belmont Ave., Chicago 10, Ill.

T-327 CENTRIFUGE. 16-page house organ, Spring 1951 issue of "The Milvay Notebook," features article on new centrifuges, laboratory mills, vacuum pumps, colorimeter and other

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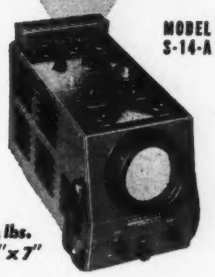

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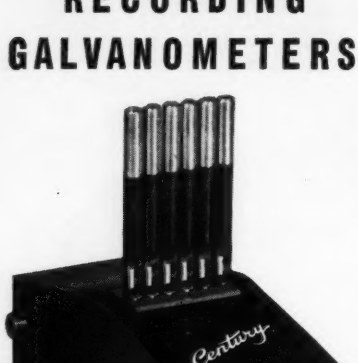

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types of laboratory equipment and supplies.—Chicago Apparatus Co., Chicago 22, Ill.

T-328 RADIATION PROTECTION. 16-page booklet discusses radiation monitoring for civil and industrial safety; discusses measurement of radiation hazards, training civilian defense personnel and instruments such as radioactivity demonstrator, alpha-beta-gamma survey meter, dosage meters etc.—Tracerlab, 130 High St., Boston 10, Mass.

T-329 SCALE. 4-page Form 668 illustrates and describes maker's "Model 77 Weightograph"; lists 20 features of this new automatic weighing accessory.—Howe Scale Co., Rutland, Vt.

T-330 VOLTAGE TRANSFORMER. 6-page Bulletin CV-112 and supplement illustrates and describes maker's constant voltage transformers to provide automatic protection against changing power loads.—Sola Electric Co., 4633 W. 16th St., Chicago 50, Ill.

T-331 SPECTRUM ANALYZER. 2-page bulletin illustrates and describes maker's spectrum analyzer; includes features, description, uses and specifications.—Vectron, Inc., 235 High St., Waltham, Mass.

T-332 PHASE METER. 2-page reprint from ELECTRONICS illustrates and describes maker's "New 320-A" phase meter to directly measure phase differences; includes maker's Z-angle meter, RF oscillator and wide-band decade amplifier.—Technology Instrument Corp., 531 Main St., Acton, Mass.

T-333 SHOCK MOUNTS. 16-page Catalog 600 illustrates and describes maker's "Vibrashock, Met-l-flex" unit type shock mounts and vibration isolators; includes construction features, performance features, engineering diagrams, weight and finish.—Robinson Aviation Inc., Teterboro, N. J.

T-334 RF COMPONENTS. 72-page Catalog 6 illustrates and describes maker's connectors and RF components, waveguide adapters and components; includes index to military and IPC numbers, cable assembly and panel mounting instructions.—Industrial Products Co., Danbury, Conn.

T-335 RECORDING EQUIPMENT. 8-page Form C1-100 describes and illustrates maker's "Magnecorder" professional tape recording equipment, portable, rack and console model recorders; includes single microphone input amplifier, amplifier and adapter panel.—Magnecord, Inc., 360 N. Michigan Ave., Chicago, Ill.

T-336 VOLTAGE-DIVIDING RESISTORS. 2-page bulletin illustrates and describes maker's "RUP3" high-precision machined aluminum-base-resistor as well as "RU3" bakelite base and "RVT" translatory models.—Technology Instrument Corp., 531 Main St., Acton, Mass.

T-337 RECORDING PAPER. 4-page bulletin discusses maker's sensitive paper to record 100 or more characters per sec. in telemetering, monitoring, high-speed communications, radar, sonar, loran, infra-red, etc.—Alfax Paper and Engineering Co., P. O. Box 125, Westboro, Mass.

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T-344 COMMUNICATION SYSTEMS. 8-page folder discusses maker's microwave communication systems and compares to wire systems; includes map of present installations and organizations served.—Industrial Div., Philco Corp., Tioga & C Sts., Philadelphia 34, Penna.

T-345 ANALOG COMPUTER. 4-page house organ "TIC Laboratory Report No. 3," features articles on analog computer recently completed for MIT and "A Production Test Method for the Determination of the Linearity of Precision Potentiometers."—Technology Instrument Corp., 531 Main St., Acton, Mass.

T-346 RECORDING COMPONENTS. 2-page Form 271-25C presents maker's recording components; includes specifications, outline drawings and dimensions.—The Brush Development Co., 3405 Perkins Ave., Cleveland 14, Ohio.

T-347 SPECIAL PLUGS, CONNECTORS. 44-page Catalog 74 lists "Amphenol" line of radio-electronic products; includes antennas, connectors, plugs, sockets, transmission lines, cable clamps and coil forms.—American Phenolic Corp., 1830 S. 45th St., Chicago 50, Ill.

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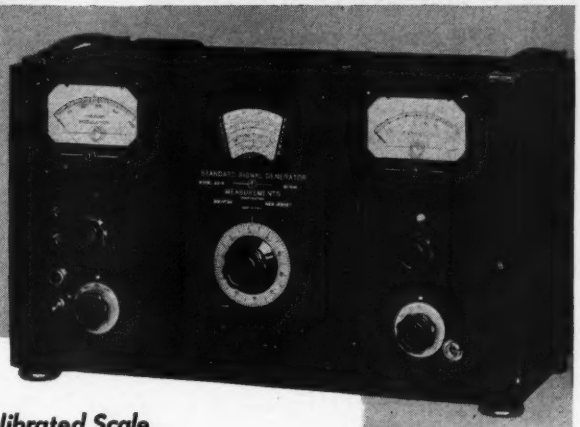

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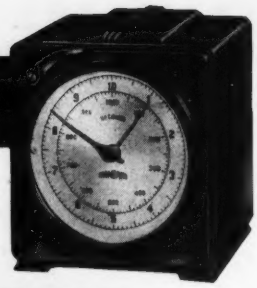

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T-365 RELAYS. 4-page Bulletin 100 illustrates and describes maker's "LM" plate circuit relays, "SU" multiple leaf relays, "MS" motor starting relays, "HG" mercury contact relays, "PR" heavy-duty power relays, etc.—Potter & Brumfield, Princeton, Indiana.

T-366 ACCELEROMETER CALIBRATION SYSTEM. 4-page Bulletin 1250 contains price list for accelerometer intermediate shaker and velocity pickup calibration systems, standards and meters.—The Calidyne Co., 751 Main St., Winchester, Mass.

T-367 OSCILLOGRAPH. 8-page folder illustrates and describes maker's "Model 640" oscillograph as well as tube testers and signal generator in laboratory, radio and TV technicians and counter models; includes specifications.—The Hickok Electrical Instrument Co., 10514 Dupont Ave., Cleveland 8, Ohio.

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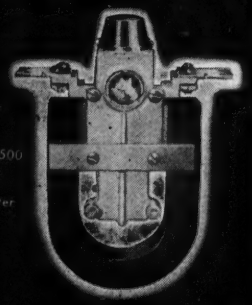

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T-372 RELAYS. 6-page Circular 1702 illustrates and describes maker's relays (Classes B, C, A and Z, aircraft, a-c., power control, and special types); includes features, applications and specifications of each.—Automatic Electric Sales Corp., 1033 W. Van Buren St., Chicago 7, Ill.

T-373 PERMANENT MAGNETS. 2-page reprint from PRODUCT ENGINEERING discusses improvements on magnet engineering and construction.—Indiana Steel Products Co., Valparaiso, Ind.

T-374 ELECTRICAL TESTER. 2-page Form 41549-T illustrates and describes maker's pocket size "Model 666-R" volt-ohm-mil-ammeter; covers ranges and general description.—The Triplett Electrical Instrument Co., Bluffton, Ohio.

T-375 PLUGS, CONNECTORS. 8-page house organ, Vol. III, No. 2 issue of "Cannonade," features article on application of maker's plugs to Beckman & Whitley 2000-mph. photo equipment, to Consolidated oscillographs; also covers moisture-proof and other connectors.—Cannon Electric Co., 3209 Humboldt St., Los Angeles 31, Calif.

T-376 OSCILLOSCOPE. 2-page bulletin illustrates and describes maker's "Model H-43" four-channel oscilloscope with separate controls for each channel and designed for strip-film recording; includes features and specifications.—Electronic Tube Corp., 1200 E. Mermaid Lane, Philadelphia 18, Penna.

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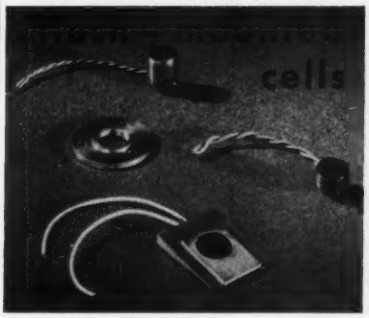

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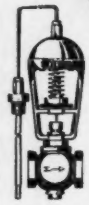

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